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QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

DEAN F. MARTIN, *Editor* BARBARA B. MARTIN, *Co-Editor*

Volume 54 Winter 1991 Number 1

Biological Sciences

STUDIES ON THE DISTRIBUTION AND ECOLOGY OF *PLATORCHESTIA PLATENSIS* (KRØYER) AT LAKE WYMAN, BOCA RATON, FLORIDA[1]

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ABSTRACT: *Quantitative samples of semiterrestrial talitrid amphipods were collected monthly, October 1985 through September 1986, at estuarine Lake Wyman in Boca Raton, Florida.* Platorchestia platensis, *the most common of four talitrid species collected, was most abundant in the supralittoral zone from October to January and in the midlittoral zone from May to September. Ovigerous females were collected throughout year, although the highest ratio of ovigerous to total adult females occurred in September. Adult females outnumbered males each month except February and September.*

Platorchestia platensis (Krøyer), a member of the gammaridean amphipod family Talitridae, occurs in North America from southern Newfoundland and the Gaspé Peninsula to southern Florida and the Gulf of Mexico (Bousfield, 1973). It is reportedly a common shore-dwelling species found in association with wrack at high water levels in the intertidal zones of rocky, gravelly, sandy, and muddy shores (Behbehani, 1978; Farrel, 1970; Feeley and Wass, 1971; Fox and Bynum, 1975; Kunkel, 1910; Morino, 1978; Teal, 1962; and Thomas, 1976). Behbehani's (1978) autoecological study of *Orchestia (=Platorchestia) platensis* in New England is the most comprehensive of these reports.

Very little published information is available on the ecology of talitrids in southern Florida. Holmquist (1982) studied variations in the functional morphology of gnathopods in relation to the habitat of several talitroidean species (Superfamily Talitroidea), including one collected from the Florida Keys. Bousfield (1982, 1984) reported on several talitrid species found in Florida, although his investigations were primarily systematic in nature.

In view of this lack of information, the purpose of our study was to describe the distribution, seasonal abundance and general ecology of *Platorchestia platensis* in an estuarine environment in southern Florida. This is the first report on the general ecology of this species in the southeastern United States.

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[1] This paper is part of a thesis by Humberto A. Garcés B. presented in partial fulfillment of the requirements for the degree of Master of Science, Florida Atlantic University, Boca Raton, Florida. 1988.

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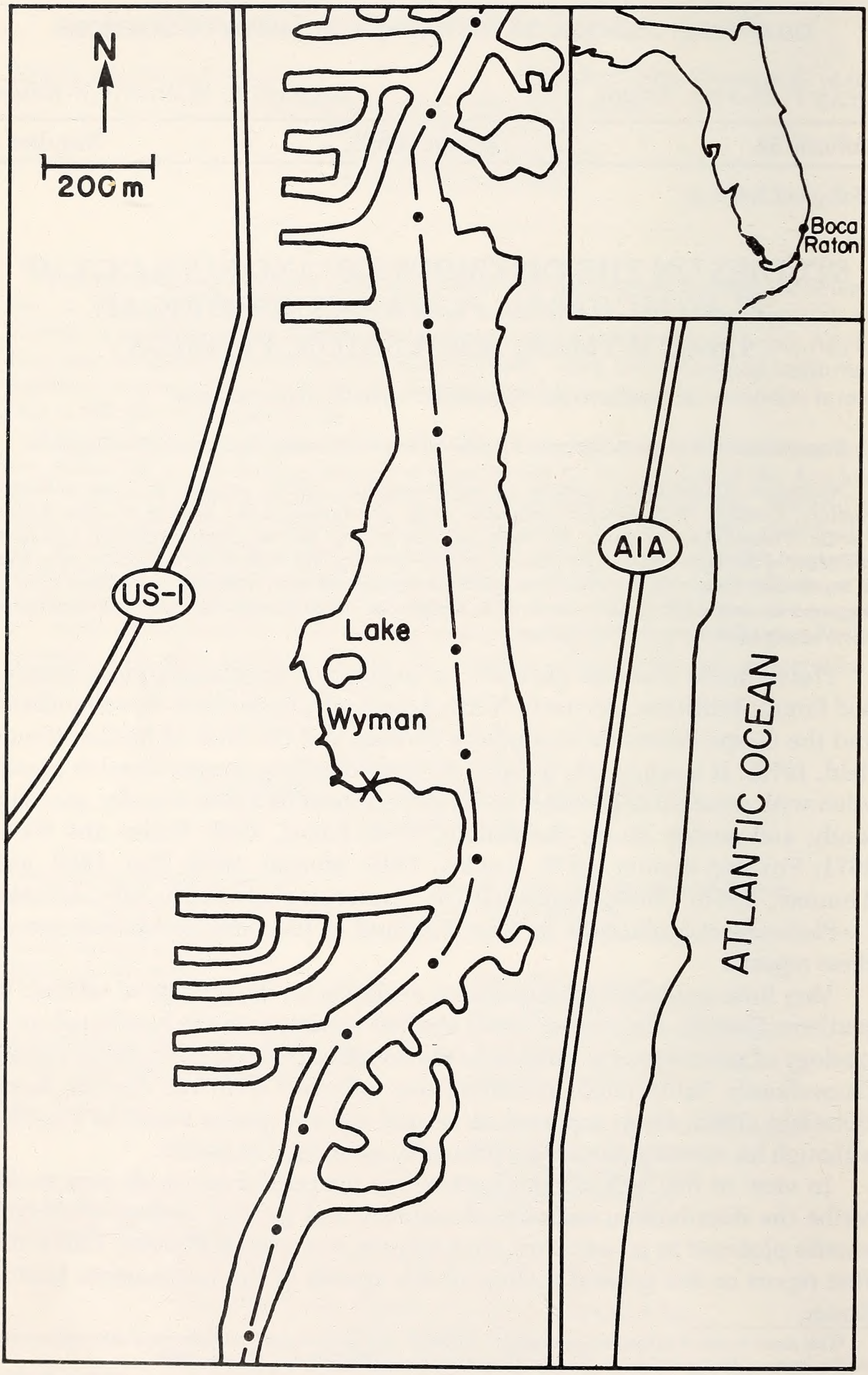

Fig. 1. Map of Lake Wyman showing general area and location of study site (X).

Description of Area—Lake Wyman (26° 21′ 50″ N; 80° 4′ 30″ W) is an expanded portion of the Atlantic Intracoastal Waterway in Boca Raton, Palm Beach County, Florida (Fig. 1). It is a shallow estuarine area surrounded by mangrove vegetation with segments of exposed sandy beach occurring primarily along the southern shoreline. The nearest outlet to the Atlantic Ocean, Boca Raton Inlet, is located approximately 3.2 km. to the south. The mean vertical tidal range at Lake Wyman is approximately 0.8 m. (U.S. Department of Commerce Tide Tables, 1987).

METHODS—Salinities in Lake Wyman, measured on site with an Atago hand refractometer (±0.5 ppt), averaged 27.5 ppt during the study period, with a range of 16.5-33.5 ppt. Lowest salinities occurred in January, March, and June 1986, corresponding to high cumulative daily rainfall values calculated for each month from data provided by the U.S. National Weather Service at Palm Beach International Airport (Fig. 2).

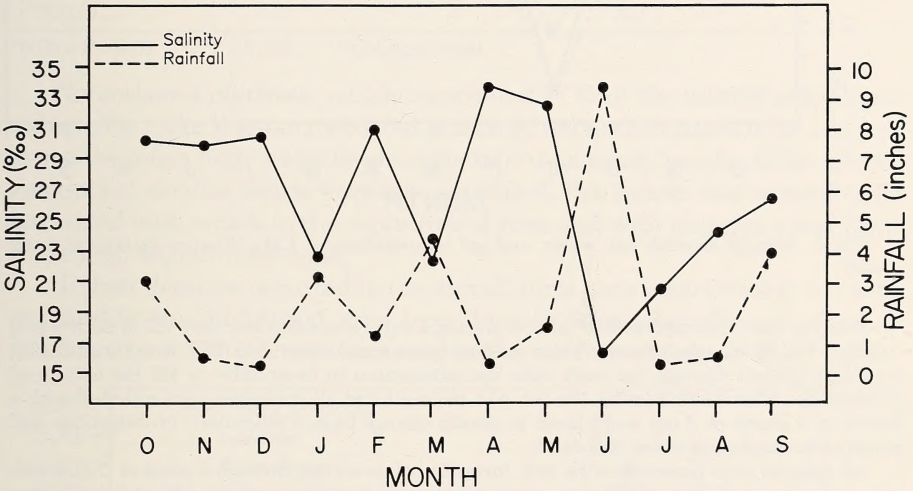

FIG. 2. Average monthly salinities at Lake Wyman and cumulative rainfall quantities at Palm Beach International Airport during the one year study period.

Air, water, and sediment temperatures, measured on site with a mercury thermometer, differed by less than 2°C within any given month (Fig. 3). The lowest temperatures (19-21°C) were recorded in January 1986 and the highest temperatures (31-33°C) in July. Sediment temperatures, measured at approximately 1 cm below the surface, were consistently lower than air or water temperatures (Fig. 3).

Sampling was conducted monthly at low tide on two consecutive days from October 1985 through September 1986 along the southern shoreline of Lake Wyman. The sampling area was divided into four adjacent 250-m^2 quadrats, each with three contiguous vertical zones: a 3-m-wide midlittoral zone, bounded by the mean high and low water marks; a 1-m-wide supralittoral zone; and a 1-m-wide high supralittoral zone at the shoreward extent of the sandy beach. This latter zone was characterized by relatively high concentrations of leaf detritus and other debris. Three random samples were collected from each of the three vertical zones within each quadrat, providing a total of 36 samples each month.

Preliminary sampling, done on three occasions in October 1985, indicated that 3 samples/zone/quadrat accounted for 90% or more of the total calculated amphipod densities based on larger sample sizes. Because of the limited duration of tidal exposure, two randomly selected quadrats were sampled on the first day and the other two quadrats were sampled on the second day of each sampling period. All collections were made 1-6 days after the first or last lunar quarter.

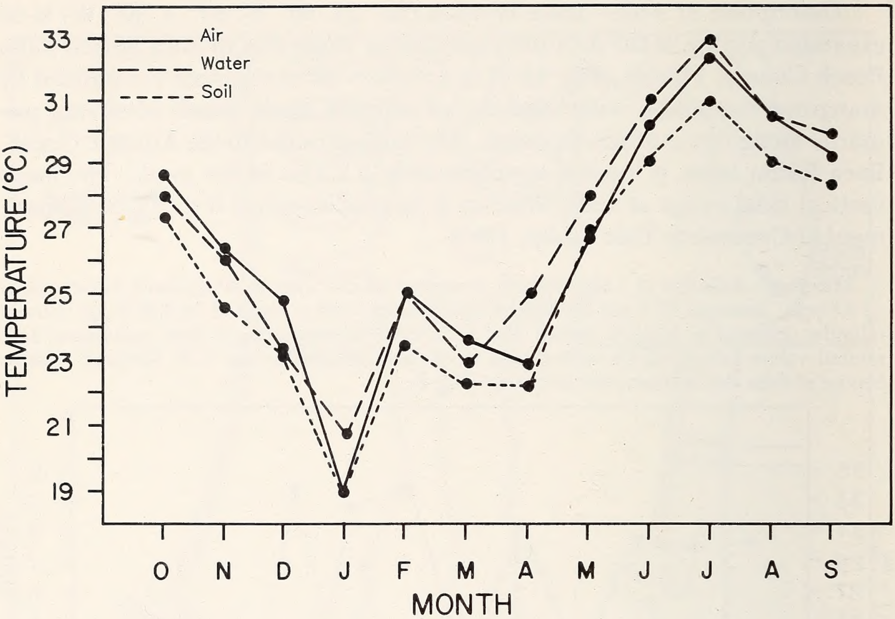

FIG. 3. Average monthly air, water, and soil temperatures at Lake Wyman during the study period.

Samples were collected at low tide by placing a square wooden box sieve (25 X 25 X 6 cm) upside down on the substratum. A non-residual commercial insecticide (Hot Shot Formula 111) was then sprayed through the mesh onto the substratum to immobilize or kill the entrapped amphipods. After 10-15 minutes the box was removed and all materials were collected with a shovel to a depth of 2 cm and placed in plastic storage bags. Preliminary investigations had revealed no amphipods below this depth.

All samples were preserved with 10% formalin before sorting through a series of U.S. standard testing sieves (2.00 to 0.500 mm. mesh size range). Amphipods retained by the sieves were preserved in 5% formalin, then were transferred to 70% ethanol after one week.

Seasonal abundance, expressed as number of individuals/m^2 for each zone and quadrat, was recorded monthly. A 3 X 4 X 6 Factorial ANOVA design was used for statistical analysis of the collections. Months (12), zones (3), and quadrats (4) were treated as Factors A, B, and C, respectively.

Size class distributions were based on percentages of individuals in each arbitrarily selected 2.5 mm size class. Morphometric measurements included total lengths of amphipods within the following categories: immature, sub-adults (with rudimentary sexual characters), and adults (sexual characters fully developed). Lengths of amphipods were measured with a metric ruler under a 10X dissecting microscope to the nearest 0.5 mm from the base of the first antenna to the tip of the telson. Curled animals were gently extended with the aid of jewelry forceps before measuring.

RESULTS—*Distribution and abundance*—Factorial analysis (Table 1) showed significant differences ($0.05 > p > 0.01$) among months and among zones, indicating seasonal changes in the vertical distribution of *Platorchestia platensis*. Interactions among the quadrats and months, and among the quadrats and zones were not significant. However, highly significant interaction ($p \leq 0.001$) among months and zones indicated seasonally differential effects on the distribution of these animals.

TABLE 1. Factorial analysis of *Platorchestia platensis* samples from Lake Wyman. Months (12), zones (3), and quadrets (4) are treated as factors A, B, and C, respectively.

Source	M.S.	df	F_s
Treatments (Sub-groups)	204.559	2	146.55***
A Months (12)	3.912	11	2.82*
B Zones (3)	18.391	2	7.11*
C Quadrats (4)	3.878	3	2.78*
First-Order Interactions			
A X B (months X zones)	7.520	22	5.45***
A X C (months X quadrats)	1.384	33	0.99$^{n.s.}$
B X C (zones X quadrats)	2.587	6	1.85$^{n.s.}$
Second-Order Interactions			
A X B X C (months X zones X quadrats)	1.378	66	0.99$^{n.s.}$
ERROR	1.395	286	
TOTAL		431	

*0.05≥P>0.01 ***P<0.001 $^{n.s.}$ not significant

Platorchestia platensis, which constituted 77% of the talitrid amphipods collected at Lake Wyman, occurred primarily under drift material at and just above the mean high water level on the intertidal sandy beach. Although the amounts of detrital debris were not quantified, this species also seemed to be associated with wrack in the supralittoral zone and with mangrove leaf litter in the high supralittoral zone.

Highest densities occurred in the supralittoral zone from October to January, and in the midlittoral zone from May to September (Fig. 4). A peak density of over 550 ind. m^{-2} was found in the midlittoral zone in May. Gener-

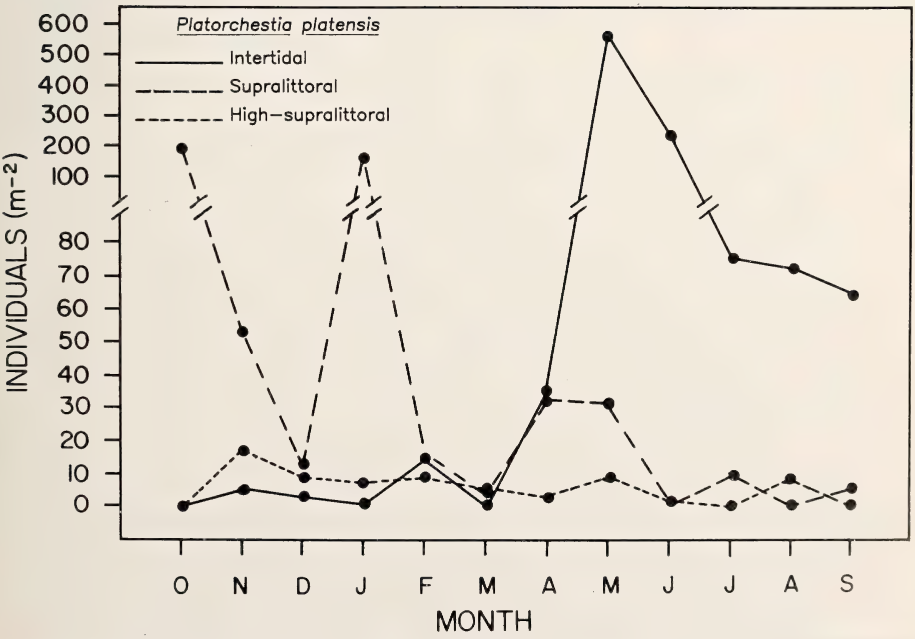

FIG. 4. Monthly zonal densities (ind. m^{-2}) of *Platorchestia platensis* at Lake Wyman during the study period.

ally lower densities (<20 individuals m^{-2}) occurred in the high supralittoral zone throughout the study period.

Size class distribution—Platorchestia platensis males attained a larger adult size than did females. Adult males ranged in length from 6.5-15.0 mm while adult females ranged from 6.5-12.5 mm. In addition, some adult *P. platensis* males (>9.0 mm) had conspicuously more robust second antennae than did other males or females. According to Bousfield (1986), this latter character distinguishes two forms of conspecific males at maturity. Mature males were distinguishable from immature males by the presence of a testicular or penile papilla at the base of the seventh pereopods and by the enlarged second gnathopods.

Seasonal trends in the representation of different size classes in the *Platorchestia platensis* population were evident (Fig. 5). Immature (1.0-3.5 mm) and sub-adult (4.0-6.5 mm) individuals constituted a majority of the total population in October and November, yielding to an apparent predominance of adult size classes (7.0-15.0 mm) from December through March. These conclusions are somewhat tenuous due to the small sample sizes in February ($n=27$) and March ($n=8$). Immature and sub-adult individuals predominated again from April through June but declined in abundance as the population aged from July to September.

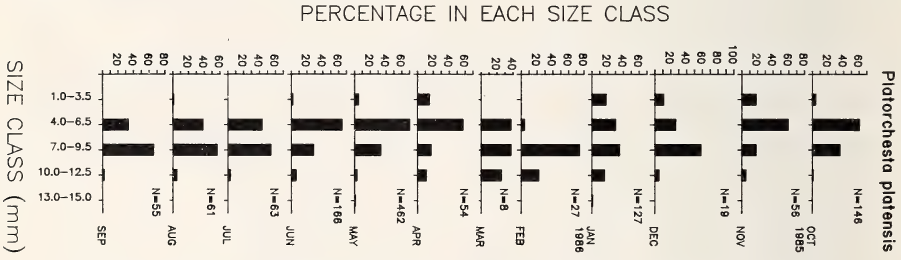

FIG. 5. Monthly size class distribution of *Platorchestia platensis* during the study period.

Reproductive activity—Observations on reproductive activity included counts of ovigerous females and male/female ratios. The ratio of ovigerous females to total adult females was used to estimate the breeding activity of the amphipods. Mature females were identified by the presence of oostegites or the presence of eggs or embryos in the marsupium. *Platorchestia platensis* ovigerous females occurred throughout the year, with 1-15 ($\bar{x}=5\pm3.0$) eggs or juveniles present in the brood chamber. The ratio of ovigerous females to total adult females ranged from 0.10 to 0.33 with a peak in September, although the mean number of eggs found per gravid female reached a peak in May ($\bar{x}=8\pm3.0$). Adult *P. platensis* females outnumbered adult males during each month except February and September (Fig. 6). The mean monthly male to female ratio for this species was 0.69. Gravid females ranged in length from 6.5 to 12.5 mm, with the largest gravid females (10.0-12.5 mm size class) occurring during two distinct periods, from January to March and from May to July. There was no apparent relationship between the number of

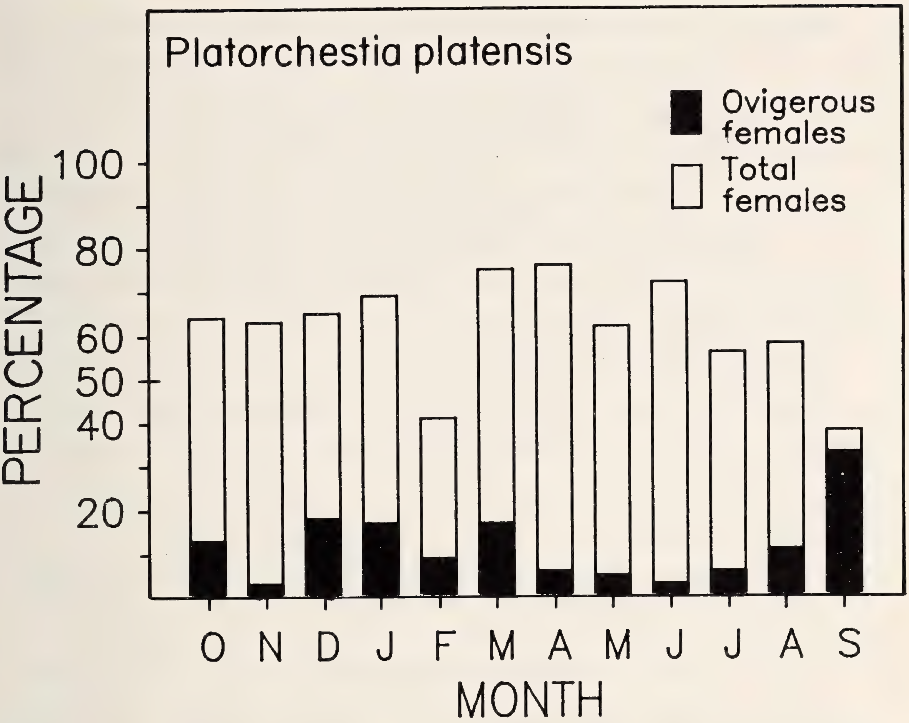

FIG. 6. Monthly changes in percentages of gravid females in total adult female population of *Platorchestia platensis.*

eggs carried per gravid female, size of gravid female, or the average egg diameter (0.6 ± 0.1 mm.).

DISCUSSION—The paucity of information available on talitrid amphipods in southern Florida is indicated by the fact that two of the four species found in the study area are at present undescribed (Garcés, 1988b). No published information is available on the distribution, general ecology, or population dynamics of *Platorchestia platensis* in this region.

Behbehani and Croker (1982) reported that population densities of *Platorchestia platensis* averaged 1,280 organisms m^{-2} in a New England beach wrack community. In contrast, the *P. platensis* population reached a peak density at Lake Wyman of only about 550 ind. m^{-2} in the midlittoral zone in May. The lower densities observed in this study may reflect differences between New England and Lake Wyman regarding the number of competing species, width of the intertidal zone, or the abundance of wrack. Relatively high densities in early summer within the midlittoral zone apparently resulted from the movement of amphipods downward from higher elevations, since these greater densities were paralleled by decreased densities in the supralittoral. These movements may have reflected the presence of additional food and shelter available in the form of drift materials washed into the midlittoral zone by strong winds during the previous weeks. The relative abundance of *P. platensis* in the supralittoral from October to February was likewise seemingly correlated with relatively large amounts of drift materials in that zone. The observed decrease in mean lengths of *P. platensis* adults during March and April apparently reflects heavy adult (>10.0 mm.) mortality as well as recruitment of juveniles into the population which continued through September.

The year-round breeding activity of *P. platensis* recorded herein for Lake Wyman is in contrast to that previously reported for New England by Behbehani and Croker (1982). They found ovigerous females from March to November, with up to five broods per year. Although Behbehani (1978) reported an average clutch size of about 18 eggs for *Platorchestia platensis* collected in New England, this species at Lake Wyman was notable for its small clutch size, averaging only 1-8 eggs per gravid female collected in any sampling period. The high female to male ratio shown for *P. platensis* in this study has also been found in many populations of the marine supralittoral genus *Orchestia.* According to Wildish (1971) this is an adaptation for increasing the reproductive potential of the population by increasing the percentage of reproductive individuals.

The distribution and abundance of semiterrestrial talitrid amphipods is influenced by favorable microclimatic conditions, such as warm temperatures and high humidities. The presence of organic wrack serves both as food and protection against dehydration (Chelazzi and Ferrara, 1978). Desiccation tolerance experiments on *Platorchestia platensis* from Lake Wyman (Garcés, 1988a) indicated a mean survival time in a desiccation chamber of 45 ± 5 min, when water loss was 30 ± 8% of the initial body content. *Platorchestia platensis* is thus restricted to damp substrata and high humidity microhabitats such as beach wrack, leaf litter, or seaweed debris.

Platorchestia platensis is reportedly omnivorous, eating fresh plant tissue, live oligochaetes, *Limulus* eggs, and diatom 'fuzz' (Behbehani and Croker, 1982). In the laboratory *P. platensis* fed actively on both fresh and decomposing leaf tissues *(Sesuvium, Casuarina), Sesuvium* stem surface epidermis, detritus, and algae.

Behbehani (1978) reported several arthropods as predators of *P. platensis* in New England, including the green crab *Carcinus maenas,* wolf spiders (Lycosidae), and the earwig *Anisolabis maritima* (Dermaptera). Tagatz (1968) has shown that amphipod remains, including those of the sandhopper *Talorchestia* sp., occurred in 62% of the stomachs of young *Callinectes* and may account for 14% of the total diet of these juvenile crabs in the St. Johns River, Florida. Dawn (1957) found the Cape May Warbler, *Dendroica tigrina,* to be a predator of *P. platensis* at Long Island, N.Y. The only known predator of talitrid amphipods at Lake Wyman is the earwig, *Labiduria riparia* (Pallas). Gut and fecal content analyses of earwigs collected in the midlittoral and supralittoral zone at Lake Wyman consistently showed small pieces of body exoskeleton and leg spines of several talitrid amphipod species.

Three symbionts, probably ectoparasites, were occasionally found in association with *Platorchestia platensis* at Lake Wyman. These included one mite, an isopod, and a ciliate (all unidentified species). Approximately 2% of the population was associated with one or more of these organisms. The mites occurred in the brood chamber or inner buccal mass of females, while isopods were found attached externally to body surfaces and appendages of both sexes. A single ciliate was found on a gravid *P. platensis* female on the outer surface of one of the eggs. Behbehani (1978) reported several symbionts found in association with *P. platensis* including a protozoan, a nematode, two species of mites, a ciliate, and an occasional fungus. At Lake Wyman, a fungal infection of the proximal end of the head and walking appendages of *P. platensis* was seen on several occasions and was most common in May 1986 when population density reached a peak. Bousfield and Heard (1986) reported that *Uhlorchestia uhleri*, a palustral talitrid amphipod, is often parasitized by protozoans and larval helminths. The effects of parasitism on the population dynamics of *P. platensis* at Lake Wyman is unknown, but it is most likely of minor importance.

ACKNOWLEDGMENTS—The authors appreciate the helpful criticisms and advice of Ralph M. Adams, Manley L. Boss, and Sheldon Dobkin (Florida Atlantic University). E. L. Bousfield (National Museum of Canada) confirmed the species identification.

LITERATURE CITED

BEHBEHANI, M. I. 1978. Studies on the ecology of *Orchestia platensis* Kroyer, 1845 (Crustacea: Amphipoda). Ph.D. dissert. Univ. Delaware, Newark, Del.

BEHBEHANI, M. I. AND R. A. CROKER. 1982. Ecology of beach wrack in northern New England with special reference to *Orchestia platensis*. Estuarine Cstl. Shelf. Sci. 15(6):611-620.

BOUSFIELD, E. L. 1973. Shallow-water gammaridean Amphipoda of New England. Cornell Univ. Press. Ithaca, NY.

__________. 1982. The amphipod superfamily Talitroidea in the northeastern Pacific region: 1. Family Talitridae: Systematics and distributional ecology. Natl. Mus. Nat. Sci., Ottawa, Publ. Biol. Oceanogr. No. 11. 73 pp.

__________. 1984. Recent advances in the systematics and the biogeography of landhoppers (Amphipoda: Talitridae) of the Indo-Pacific region. Proc. ASC Symp. Biogeogr. Trop. Pacific. Bishop Mus. Spec. Publ. No. 72:170-210.

__________. 1986. National Museum of Canada, Ottawa, Personal Communication.

BOUSFIELD, E. L. AND R. W. HEARD. 1986. Systematics, distributional ecology, and some host-parasite relationships of *Uhlorchestia uhleri* (Shoemaker) and *U. spartinophila* new species (Crustacea: Amphipoda), endemic to salt marshes of the Atlantic coast of North America. J. Crust. Biol. 6(2):264-274.

CHELAZZI, G. AND F. FERRARA. 1978. Researchers on the coast of Somalia, the shore and the dune of Sar Uanle. Monitore Zool. Ital. 8:189-219.

DAWN, W. 1957. Cape May warbler feeds on amphipods. Auk 74(1):98.

FARREL, D. H. 1970. Ecology and seasonal abundance of littoral amphipods from Mississippi. M.S. thesis. Miss. State Univ. State College.

FEELEY, J. B. AND M. L. WASS. 1971. The distribution and ecology of the gammaridea (Crustacea: Amphipoda) of the lower Chesapeake estuaries. Special papers in Marine Science, Virginia Inst. Mar. Sci. 2:1-58.

FOX, R. S. AND K. H. BYNUM. 1975. The amphipod crustaceans of North Carolina estuarine waters. Chesapeake Sci. 16(4):223-237.

GARCÉS, H. A. 1988a. Desiccation tolerance of *Platorchestia platensis* (Krøyer, 1845) (Amphipoda: Talitridae). Rev. Biol. Trop. 36(1):63-66.

__________. 1988b. Distribution and ecology of talitrid amphipods at Lake Wyman, Boca Raton, Florida. M.S. thesis. Florida Atlantic Univ., Boca Raton, FL.

HOLMQUIST, J. G. 1982. The functional morphology of gnathopods: Importance in grooming, and variation with regard to habitat, in talitroidean amphipods. J. Crustacean Biol. 2(2):159-179.

KUNKEL, B. W. 1910. The amphipoda of Bermuda. Trans. Conn. Acad. Arts. Sci. 16:1-115.

MORINO, H. 1978. Studies on the Talitridae (Amphipoda, Crustacea) in Japan. 3. Life history and breeding activity of *Orchestia platensis* Krøyer. Publ. Seto Mar. Biol. Lab. 24 (4/6):245-267.

TAGATZ, M. E. 1968. Biology of the blue crab, *Callinectes sapidus* Rathburn in the St. Johns river, Florida. U.S. Fish and Wildl. Serv. Fish. Bull. 67(1):17-33.

TEAL, J. M. 1962. Energy Flow in the salt marsh ecosystem of Georgia. Ecology 43(4):614-624.

THOMAS, J. D. 1976. A survey of gammarid amphipods of the Barataria Bay, Louisiana region. Contr. Mar. Sci. 20:87-100.

U.S. DEPARTMENT OF COMMERCE. 1987. Tide tables 1988. East Coast of North and South America. U.S. Government Printing Office, Washington, D.C. 289 pp.

WILDISH, D. J. 1971. Adaptive significance of a biased sex ratio in *Orchestia.* Nature (London) 233:54-55.

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Accepted: March 13, 1990.

SPOTTED SKUNK USE OF A GOPHER TORTOISE BURROW FOR BREEDING

—*Brian Toland,* Office of Environmental Services, Florida Game and Fresh Water Fish Commission, Vero Beach, Florida 32968

ABSTRACT: *An active gopher tortoise* (Gopherus polyphemus) *burrow was used by an eastern spotted skunk* (Spilogale putorius) *for escape cover during winter. The burrow was subsequently utilized by the skunk as a winter den during late winter and early spring. This commensal relationship ended when spotted skunks apparently usurped the burrow, enlarged it, and utilized it to successfully raise 3 young.*

A TOTAL of approximately 60 species of vertebrates is known to occur in association with gopher tortoise *(Gopherus polyphemus)* burrows as accidental, occasional, or obligate residents (Speake 1981, Cox et al. 1987, Jackson and Milstrey in press). Burrow commensals even make use of the smaller burrows of juvenile tortoises (Dietlein and Franz 1979). Tortoise burrows are used as foraging sites (Young and Goff 1939, Woodruff 1982, Eisenberg 1983, Frank and Lips 1989), wintering refugia (Manaro 1961), breeding sites (Speake 1981, Campbell and Christman 1982), food caching sites (Frank and Lips 1989), and escape cover (pers. obser.).

The 21 species of mammals previously reported to use gopher tortoise burrows (Cox et al. 1987, Frank and Lips 1989, Jackson and Milstrey in press) include several carnivores that Cox and co-workers (1987) classified as "occasional" or "accidental" burrow users. Manaro (1961) reported eastern spotted skunk *(Spilogale putorius)* use of gopher tortoise burrows as den sites in Volusia County, Florida, but did not comment on whether or not the burrows were still occupied by tortoises. Frank and Lips (1989) trapped 2 spotted skunks from inactive tortoise burrows during the fall and 1 spotted skunk from an active burrow during spring. Their observations of spotted skunks at

Archbold Biological Station, Highlands County, Florida suggested that spotted skunk use of gopher tortoise burrows in southern Florida may not be unusual. Gopher tortoise burrows provide a stable microclimate (Douglass and Layne 1978) as well as concentrations of potential prey species such as invertebrates, amphibians, reptiles, and small mammals (Cox et al. 1987, Frank and Lips 1989, Jackson and Milstrey in press). This note reports use of a gopher tortoise burrow by spotted skunks for escape cover, winter refugia, and successful breeding.

The observations were made while I was sampling small mammal populations as part of a comprehensive wildlife habitat use study on land owned by I.M.C. Fertilizer, Inc., located 2 miles southeast of Bartow, Florida in Polk County. The study area is a 52-ha clay settling area reclaimed in 1984 with a deep sand tailings cap and subsequently planted with 28 species of trees, shrubs, grasses and herbs to achieve a density of from 30 to 120 plants per ha. The habitat now consists of a dense cover of natal grass *(Reimarachloa repens)* and hairy indigo *(Indigofera hirsuta)* interspersed with young sand pines *(Pinus clausa)*, long leaf pines *(P. palustris)*, and willow *(Salix caroliniana)* heads. Shortly after habitat reclamation efforts were initiated on this area, gopher tortoises were introduced as part of a relocation project.

On the morning of 22 December 1987, a spotted skunk caught by its tail in a Sherman trap quickly ran into an active tortoise burrow when released. On the following morning the skunk was again caught by its tail in the same trap and again ran into the nearby tortoise burrow when released. Close inspection of the burrow entrance revealed spotted skunk tracks superimposed over fresh tortoise tracks, an indication of continued tortoise activity (Auffenburg and Franz 1982).

During the last 2 weeks of January 1988, the gopher tortoise burrow was inspected 4 times and although there was no sign of recent tortoise activity, both tracks and scent indicated continued use by a spotted skunk.

On 10 June 1988 at 1930 h., I observed an adult spotted skunk walking toward the tortoise burrow carrying an unidentified prey item. The adult skunk was met at the burrow entrance by 3 half-grown juveniles. I again observed the 3 young skunks the next morning at 0700 h. as they loafed near the entrance. They retired to the burrow interior as I approached. At this time, the burrow entrance appeared to have been enlarged by the skunks, giving the hole a rounder shape than the typical crescent shaped entrance of a gopher tortoise burrow.

When the burrow was checked on 24 September 1988, there was no evidence of spotted skunk or gopher tortoise occupancy. Heavy rains had washed in much of the burrow.

My observations revealed an apparent eastern spotted skunk-gopher tortoise commensal relationship during the winter. Use of the tortoise burrow as a breeding den by the spotted skunks was apparently not compatible with continued burrow use by gopher tortoises.

Acknowledgments—This manuscript was improved by the comments of B.S. Barnett, J. N. Layne, and an anonymous reviewer.

LITERATURE CITED

Auffenberg, W. and R. Franz. 1982. The status and distribution of the gopher tortoise *(Gopherus polyphemus)*. Pp. 95-126. *In:* North American Tortoises: Conservation and Ecology. Wildlife Research Report 12. U.S. Fish and Wildlife Service, Washington, D.C.

Campbell, H. W. and S. P. Christman. 1982. The herpetological components of Florida sandhill and sand pine scrub associations. Pp. 163-171. *In:* Scott, N. J., (ed.). Herpetological Communities. U.S. Fish and Wildlife Service, Wildl. Res. Rep. 13. Washington, D.C.

Cox, J., D. Inkley and R. Kautz. 1987. Ecology and habitat protection needs of gopher tortoise *(Gopherus polyphemus)* populations found on lands slated for large-scale development in Florida. Nongame Wildl. Program Tech. Rep. No. 4. 69 pp. Tallahassee.

Dietlein, N. E. and R. Franz. 1979. Status and habits of *Gopherus polyphemus*. Pp. 175-180. *In:* St. Amant, E. (ed.). Desert Tortoise Council Proc. 1979 Symp.

Douglass, J. F. and J. N. Layne. 1978. Activity and thermoregulation of the gopher tortoise *(Gopherus polyphemus)* in southern Florida. Herpetologica 34: 359-374.

Eisenberg, J. F. 1983. The gopher tortoise as a keystone species. Pp. 1-4. *In:* Bryant, R. J. and R. Franz (eds.). The gopher tortoise: a Keystone Species. Proc. 4th Ann. Mtg. Florida State Museum, Gainesville, FL.

Frank, P. A. and K. R. Lips. 1989. Gopher tortoise burrow used by long-tailed weasels and spotted skunks. Fla. Field Nat. 17:20-22.

Jackson, D. R. and E. G. Milstrey. In press. The fauna of gopher tortoise burrows. Pp. 000-000. *In:* Diemer, J., D. R. Jackson, J. L. Landers, J. N. Layne, and D. A. Wood (eds.). Proc. Gopher Tortoise Relocation Symposium. Tallahassee, Florida: Florida Game and Fresh Water Fish Comm.

Manaro, A. J. 1961. Observations on the behavior of the spotted skunk in Florida. Quart. J. Fla. Acad. Sci. 24:59-63.

Speake, D. W. 1981. The gopher tortoise burrow community. Pp. 44-47. *In:* Lohoefener, R., L. Lohemeier, and G. Johnston (eds.). The Future of Gopher Tortoise Habitats. Proc. 2nd Annu. Mtg. Gopher Tortoise Council. Florida State Museum, Gainesville, FL.

Woodruff, R. E. 1982. Arthropods of gopher burrows. Pp. 24-48. *In:* Franz, R. and R. J. Bryant (eds.). The Gopher Tortoise and Its Sandhill Habitat. Proc. 3rd Annu. Mtg. Gopher Tortoise Council. Florida State Museum, Gainesville, FL.

Young, F. N. and C. C. Goff. 1939. An annotated list of the arthropods found in the burrows of Florida gopher tortoise, *Gopherus polyphemus* (Daudin). Florida Entomol. 22:53-62.

Florida Scient. 54(1):10-12. 1991.
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AN ILLUSTRATED KEY TO THE CRAYFISHES OF FLORIDA (BASED ON FIRST FORM MALES)

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Abstract: *This illustrated key to the crayfishes of Florida is offered to accompany the update of the crayfishes of the state compiled by Richard and Shelley Franz (1990). Fifty-five species and subspecies are included herein, and those couplets of the key that might prove to be troublesome contain references to figures that we hope will be helpful.*

Although this key was prepared before we learned that Franz and Franz (1990) had completed their up-date of *The Crayfishes of Florida* (Hobbs, 1942), the illustrations had not been completed. Becoming aware of their manuscript, we have added the illustrations and are offering a key which we hope will complement their contribution.

With labeled illustrations supplementing the key, only a few explanations seem to us to be necessary. If first form (breeding) males are at hand and careful comparisons of their non-secondary sexual characters with those of second form (non-breeding) males and females from the same locality, the identification of Florida crayfish populations should not prove to be difficult. Figures 28-82 include illustrations of the distal part of the left first pleopods of each of the species now known to occur within the political boundaries of the state.

Perhaps the predominant problem that has had to be faced by neophytes of crayfish identification is the recognition of *first form*, as opposed to *second form*, males. While there are several features that make the distinction possible, only a single feature is completely reliable. Unless one is decidedly near-sighted, some sort of magnification (a stereoscopic microscope is preferable, but a hand lens will usually suffice) is essential. *In all first form males at least one terminal element of the first pleopod is corneous* (exhibiting the texture of horn or a fingernail, and it is often yellowish to dark brown, occasionally even partly black). In *second form males all of the terminals are of the same texture and, except rarely, of the same color.* In general, the subterminal setae of the pleopod, which often obscure one or more of the terminal elements, are more abundant in first form males than they are in the non-breeding second form individuals, and it is sometimes necessary to remove at least some of them so that the texture of the terminals may be ascertained. For ease of comparison with the illustrations provided, we suggest that in using the key the *left first pleopod* of the crayfish (that on the observer's right when the crayfish is viewed ventrally) be examined. The directional adjectives applied to the pleopod in the key are based upon the pleopod's being

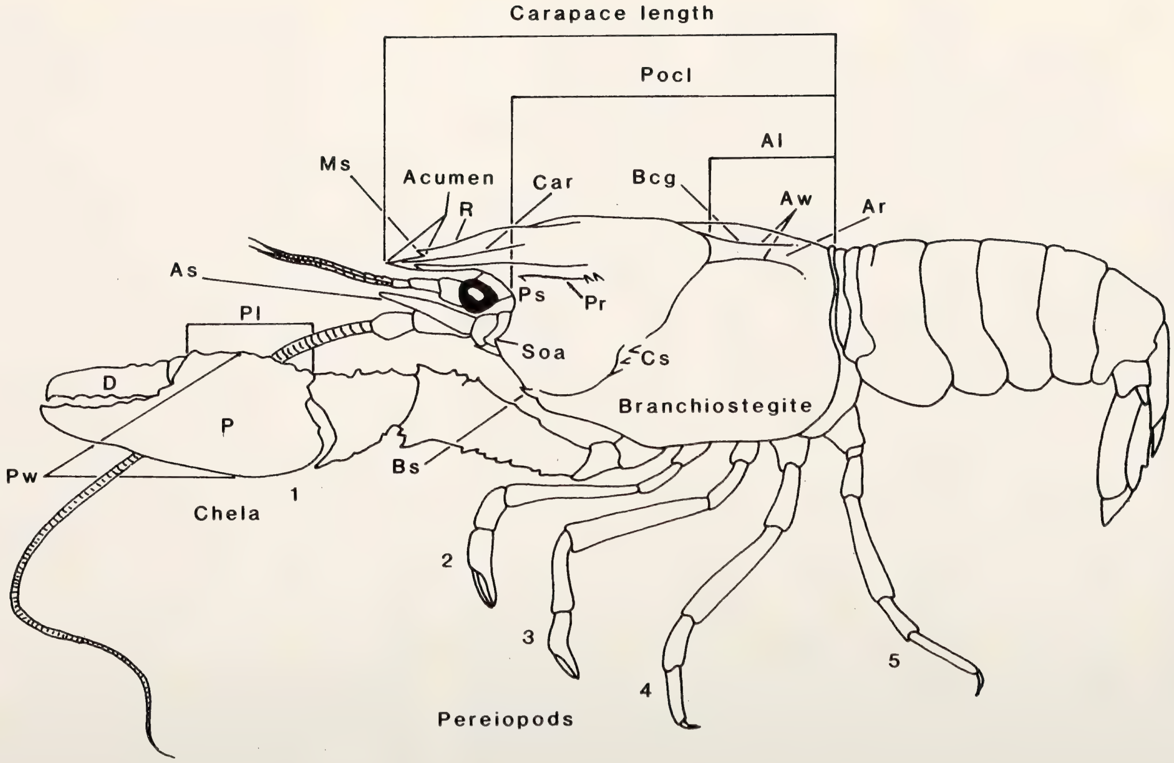


FIG. 1. Generalized crayfish illustrating most features other than secondary sexual characters used in key. Al, areola length; Ar, areola; As, antennal scale; Aw, areola width; Bcg, branchiocardiac groove; Bs, branchiostegal spine; Car, rostral carina; Cs, cervical spines; D, dactyl of chela; Ms, marginal spine; P, palm of chela; Pl, length of palm; Pocl, postorbital carapace length; Pr, postorbital ridge; Ps, postorbital spine; Pw, width of palm; Soa, suborbital angle.

considered to be hanging pendant at a right angle to the longitudinal axis of the body. Thus, the side of the appendage facing forward (and, except during amplexus, pressed against the sternum of the cephalothorax) is the *cephalic* side; that facing the rear of the animal is the *caudal* side; that facing the other member of the paired pleopods is the *mesial* side; and that seen from the side of the body is the *lateral* one.

The Key

1 Albinistic; eyes without pigment or with small pigment spot 2

1′ Body pigmented, eyes well developed and pigmented 14

2(1) Ischium of third maxilliped (most posterior oral appendage) without teeth mesially (Fig. 2) .... *Troglocambarus maclanei* Hobbs, 1942

2′ Ischium of third maxilliped with teeth mesially (Fig. 3) 3

3(2′) Hooks on ischium of third pereiopods only (Fig. 4, H) .... *Cambarus (Jugicambarus) cryptodytes* Hobbs, 1941

3′ Hooks on ischia of third and fourth pereiopods (Fig. 5) 4

4(3′) Hooks on ischia of fourth pereiopods bituberculate (Fig. 6)........ .... *Procambarus (Lonnbergius) acherontis* (Lonnberg, 1895)

4′ Hooks on ischia of fourth pereiopods simple (Fig. 5) 5

5(4′) Eyes with small pigment spot 6

5′ Eyes without pigment 10

6(5) Mesial process of first pleopod (abdominal appendage) extending distally in sinuous curve (Fig. 39); coxa of fourth pereiopod without boss .... *Procambarus (Leconticambarus) milleri* Hobbs, 1971

6′ Mesial process of first pleopod directed caudodistally (Figs. 28, 30, 31, 33); coxa of fourth pereiopod with boss (Fig. 4, B) 7

7(6′) Cephalic process of first pleopod situated lateral to central projection (Fig. 33) .... *Procambarus (Ortmannicus) orcinus* Hobbs and Means, 1972

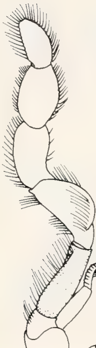
7′ Cephalic process of first pleopod situated cephalic to and partly hooding central projection (Figs. 8, 28, 30, 31) 8

8(7′) First pleopod with small caudal process (Fig. 8); pigment spot on eye black .... *Procambarus (Ortmannicus) lucifugus alachua* (Hobbs, 1940)

8′ First pleopod lacking caudal process (Figs. 9, 30, 31); pigment spot on eye black or red 9

9(8′) Rostral margins convex laterally (Fig. 22); pigment spot on eye red; antennal scale less than twice as long as broad .... *Procambarus (Ortmannicus) erythrops* Relyea and Sutton, 1975

9′ Rostral margins subparallel basally and convergent distally (Fig. 23); pigment spot on eye black; antennal scale at least twice as long as broad .... *Procambarus (Ortmannicus) leitheiseri* Franz and Hobbs, 1983



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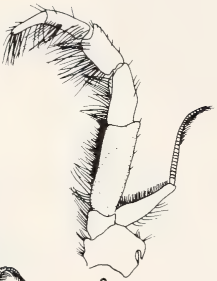

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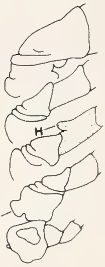

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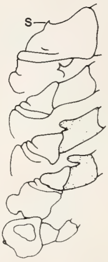

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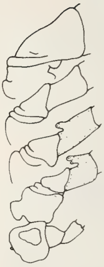

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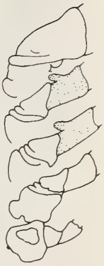

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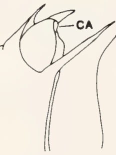

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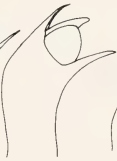

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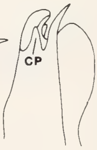

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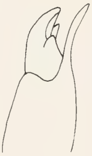

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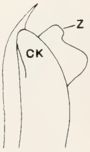

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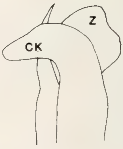

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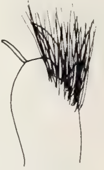

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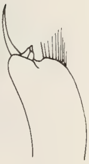

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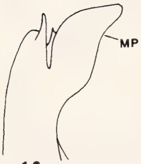

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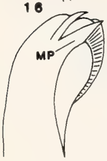

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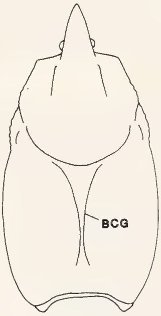

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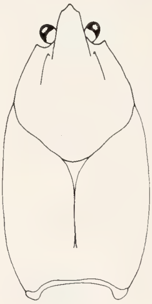

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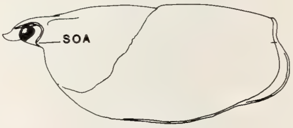

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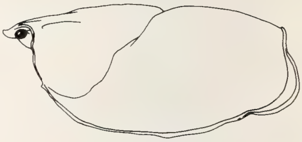

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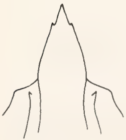

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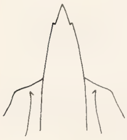

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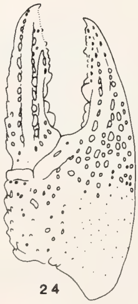

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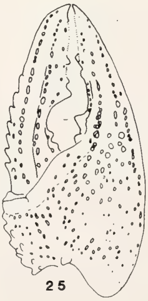

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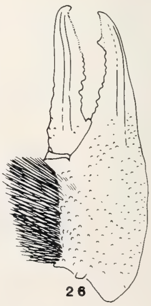

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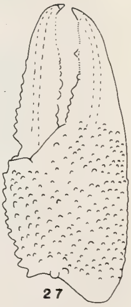

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10(5′) Anteroventral area of branchiostegite with distinct bulge (Fig. 18) . . . . . *Procambarus (Ortmannicus) delicatus* Hobbs and Franz, 1986

10′ Anteroventral area of branchiostegite lacking bulge (Fig. 19) . . . 11

11(10′) Cephalic process of first pleopod lying cephalic to central projection (Figs. 29, 32) 12

11′ Cephalic process of first pleopod lying entirely or mostly lateral to central projection (Figs. 34, 35) 13

12(11) Areola less than 18 times as long as broad . . . . *Procambarus (Ortmannicus) franzi* Hobbs and Lee, 1976

12′ Areola more than 18 times as long as broad . . . . *Procambarus (Ortmannicus) lucifugus lucifugus* (Hobbs, 1940)

13(11′) Areola less than 20 times as long as broad; postorbital ridge with spines or tubercles posteriorly (Fig. 1, Pr); cephalic process of first pleopod situated lateral to central projection (Fig. 34) . . . . *Procambarus (Ortmannicus) horsti* Hobbs and Means, 1972

13′ Areola more than 20 times as long as broad; postorbital ridges without spines or tubercles posteriorly; cephalic process of first pleopod situated cephalic to and partly hooding central projection (Fig. 35) . . . . *Procambarus (Ortmannicus) pallidus* (Hobbs, 1942)

14(1′) First pleopod terminating in long tapering projection, sometimes flanked by very small one (Fig. 49), crossing that of other member of pair . . . . *Faxonella clypeata* (Hay, 1899)

14′ First pleopod terminating in 2 or more elements (Figs. 40-48, 50-82), never with long tapering one crossing that of other member of pair 15

15(14′) First pleopod terminating in 2 elements bent caudally at at least 90 degrees to shaft of appendage (Figs. 40, 43-48) 16

15′ First pleopod never terminating in only 2 elements bent caudally at 90 degrees to shaft of appendage 22

16(15) Branchiocardiac grooves contiguous along part of their lengths (Fig. 19) 17

FIGS. 2-27. Illustrations of characters used in key: 2, ventral view of third maxilliped (ischium stippled) of *Troglocambarus maclanei;* 3, same of *Procambarus (O.) pallidus;* 4-7, ventral view of basal podomeres of pereiopods (hooked ischia stippled); 8-11, mesial view of distal part of first pleopod of first form male (8, *P. (O.) lucifugus alachua;* 9, *P. (O.) leitheiseri*, 10, *P. (Pennides) suttkusi*, 11, *P. (Pe.) spiculifer);* 12, 13, caudal view of first pleopods of first form male (12, *P. (Hagenides) rogersi campestris*, 13, *P. (H.) r. rogersi);* 14, 15, lateral view of distal part of first pleopod of first form male showing distribution of subapical setae (14, *P. (O.) seminolae*, 15, *P. (Leconticambarus) p. pubischelae);* 16, 17, mesial view of distal part of first pleopod of first form male (16, *P. (Leconticambarus kilbyi*, 17, *P. (L.) hubbelli);* 18, 19, dorsal view of carapace (18, *P. (O.) delicatus*, 19, *Cambarus (Lacunicambarus) diogenes);* 20, 21, lateral view of carapace (20, *C. (L.) diogenes; 21, C. (Depressicambarus) striatus);* 22, 23, dorsal view of rostrum (22, *P. (O.) erythrops*, 23, *P. (O.) leitheiseri);* 24-27, dorsal view of chela (24, *C. (L.) diogenes*, 25, *Fallicambarus (Creaserinus) fodiens*, 26, *P. (L.) hubbelli*, 27, *P. (L.) rathbunae).* (B, boss on coxa; BCG, branchiocardiac groove; CA, caudal process; CK, caudal knob; CP, cephalic process; H, hook on ischium; MP, mesial process; S, spine on basis of cheliped; SOA, suborbital angle; Z, central projection.)

16′ Branchiocardiac grooves not contiguous along any part of their lengths (Figs. 1, 18) 20

17(16) Opposable margin of dactyl of chela concave but without distinct excision near base (Fig. 24) 18

17′ Opposable margin of dactyl of chela with distinct, often subangular excision near base (Fig. 25) 19

18(17) Suborbital angle acute (Fig. 20); distalmost terminal element short with broadly rounded or truncate free extremity (Fig. 46) .... *Cambarus (Lacunicambarus) diogenes* Girard, 1852

18′ Suborbital single obtuse or rudimentary (Fig. 21); distalmost terminal element long and scythe-like (Fig. 44) .... *Cambarus (Depressicambarus) striatus* Hay, 1902

19(17′) Main axis of pleopod curved distinctly caudally (Fig. 47) .... *Fallicambarus (Creaserinus) byersi* (Hobbs, 1941)

19′ Main axis of pleopod almost straight (Fig. 48) .... *Fallicambarus (Creaserinus) fodiens* (Cottle, 1863)

20(16′) Length of areola less than 35 percent of entire length of carapace .. .. *Cambarus (Depressicambarus) latimanus* (LeConte, 1856)

20′ Length of areola more than 35 percent of entire length of carapace 21

21(20′) Suborbital angle absent; color orange-red .... *Cambarus (Depressicambarus) pyronotus* Bouchard, 1978

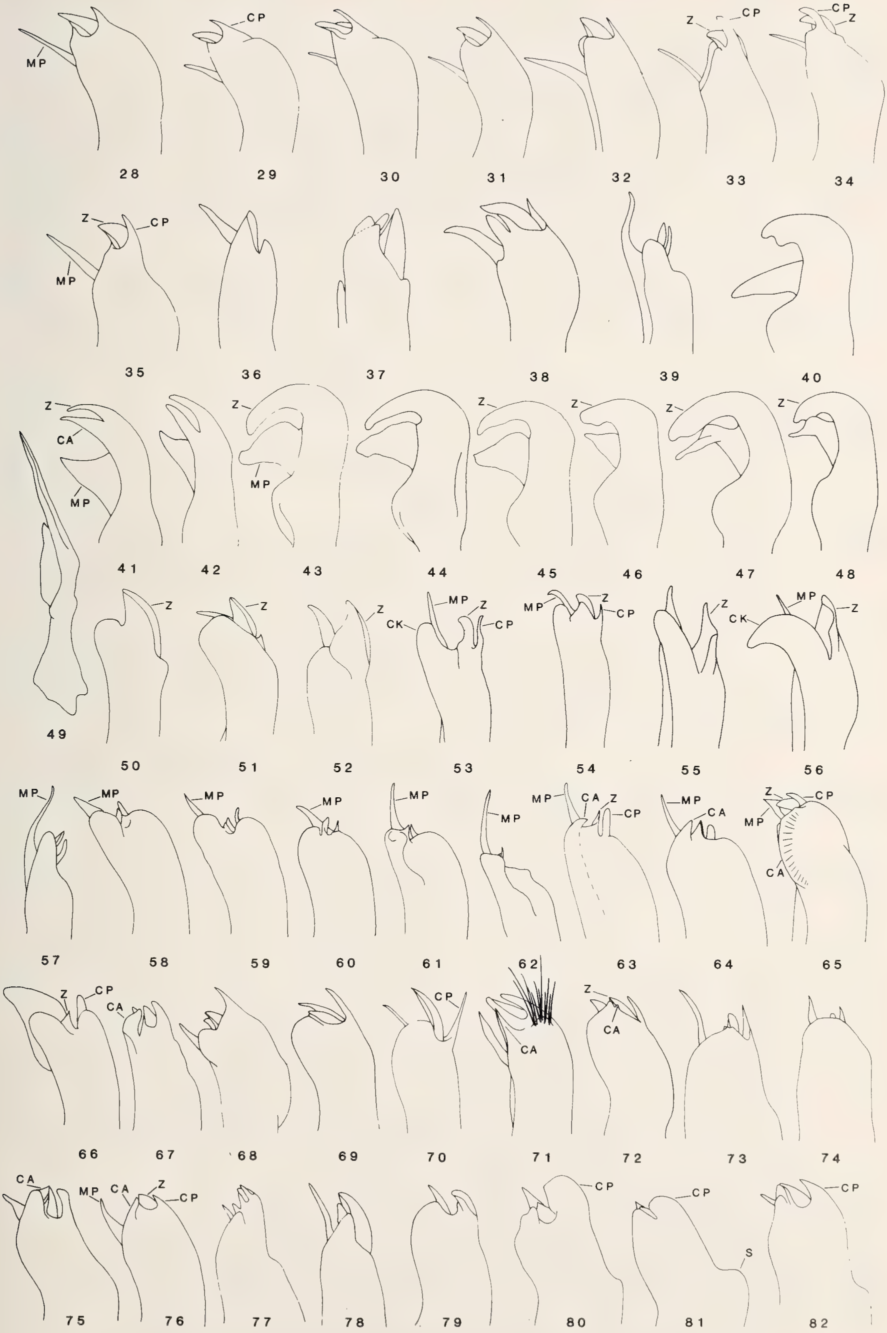
21′ Suborbital angle obtuse or rudimentary; color dark tan, brown, or blue .... *Cambarus (Depressicambarus) striatus* Hay, 1902

22(15′) Carapace with 2 cervical spines on each side (Fig. 1) 23

22′ Carapace with 0 or 1 cervical spine on each side 25

23(22) Rostrum with dorsomedian carina (Fig. 1); basis (second joint from base) of cheliped with mesial spine (Fig. 5, S) .... *Procambarus (Pennides) versutus* (Hagen, 1870)

FIGS. 28-82, First pleopods of males of Florida crayfishes (all from first form males except fig. 36, which from second form male, and all in lateral view except 49 which in caudal view; setae not illustrated except in fig. 71): 28, *Procambarus (Ortmannicus) lucifugus alachua;* 29, *P. (O.) l. lucifugus;* 30, *P. (O.) erythrops;* 31, *P. (O.) leitheiseri;* 32, *P. (O.) franzi;* 33, *P. (O.) orcinus;* 34, *P. (O.) horsti;* 35, *P. (O.) pallidus;* 36, *P. (O.) delicatus;* 37, *P. (Lonnbergius) acherontis;* 38, *Troglocambarus maclanei;* 39, *P. (Leconticambarus) milleri;* 40, *Cambarus (Jugicambarus) cryptodytes;* 41, *Cambarellus (Pandicambarus) blacki;* 42, *C. (P.) schmitti;* 43, *Cambarus (Depressicambarus) latimanus;* 44, *C. (D.) striatus;* 45, *C. (D.) pyronotus;* 46, *C. (Lacunicambarus) diogenes;* 47, *Fallicambarus (Creaserinus) byersi*, 48, *F. (C.) fodiens;* 49, *Faxonella clypeata;* 50, *P. (Hagenides) talpoides;* 51, *P. (H.) geodytes;* 52, *P. (H.) pygmaeus;* 53, *P. (H.) rogersi expletus;* 54, *P. (H.) r. ochlocknensis;* 55, *P. (H.) r. campestris;* 56, *P. (H.) r. rogersi;* 57, *P. (Leconticambarus) alleni;* 58, *P. (L.) apalachicolae;* 59, *P. (L.) econfinae;* 60, *P. (L.) escambiensis;* 61, *P. (L.) p. pubischelae;* 62, *P. (L.) latipleurum;* 63, *P. (L.) rathbunae;* 64, *P. (L.) capillatus;* 65, *P. (L.) hubbelli;* 66, *P. (L.) kilbyi;* 67, *P. (L.) shermani;* 68, *P. (Ortmannicus) pictus;* 69, *P. (O.) youngi;* 70, *P. (O.) seminolae;* 71, *P. (O.) a. acutus;* 72, *P. (O.) fallax;* 73, *P. (O.) leonensis;* 74, *P. (O.) pycnogonopodus;* 75, *P. (O.) bivittatus;* 76, *P. (O.) evermanni;* 77, *P. (Pennides) versutus;* 78, *P. (P.) spiculifer;* 79, *P. (P.) suttkusi;* 80, *P. (Scapulicambarus) clarkii;* 81, *P. (S.) okaloosae;* 82, *P. (S.) paeninsulanus.* (CA, caudal process; CK, caudal knob; CP, cephalic process; MP, Mesial process; S, shoulder; Z, central projection.)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23′ Rostrum without dorsomedian carina; basis of cheliped lacking mesial spine 24

24(23′) Cephalic process of first pleopod present on mesial side of central projection (Fig. 10) .... *Procambarus (Pennides) suttkusi* Hobbs, 1953

24′ Cephalic process of first pleopod absent (Fig. 11) .... *Procambarus (Pennides) spiculifer* (LeConte, 1856)

25(22′) Width of palm (Fig. 1, Pw) of chela greater than length of mesial margin (Fig. 1, Pl) 26

25′ Width of palm of chela less than length of mesial margin 32

26(25) Hooks on ischia of third and fourth pereiopods (Fig. 5) .... *Procambarus (Hagenides) geodytes* Hobbs, 1942

26′ Hooks on ischia of third pereiopods only (Fig. 4) 27

27(26′) Central projection of first pleopod flattened laterally and acute (Figs. 50-52) 28

27′ Central projection of first pleopod flattened anteroposteriorly and broad distally (Figs. 12, 13, 53-56) 29

28(27) Base of central projection of first pleopod spanning about 3/4 diameter of distal part of appendage (Fig. 52); color green with scarlet markings .... *Procambarus (Hagenides) pygmaeus* Hobbs, 1942

28′ Base of central projection of first pleopod spanning no more than 1/2 diameter of distal part of appendage (Fig. 50); color brown to blue .... *Procambarus (Hagenides) talpoides* Hobbs, 1981

29(27′) Caudal knob of first pleopod disposed laterally at 90 degrees to shaft of appendage (Figs. 13, 56) .... *Procambarus (Hagenides) rogersi rogersi* (Hobbs, 1938)

29′ Caudal knob of first pleopod disposed distolaterally (Figs. 12, 53-55) 30

30(29′) Cephalic process of first pleopod rudimentary or absent (Fig. 55) .... *Procambarus (Hagenides) rogersi campestris* Hobbs, 1942

30′ Cephalic process of first pleopod well developed (Figs. 53, 54) .. 31

31(30) Cephalic process of first pleopod reaching as far distally as central projection (Fig. 53) .... *Procambarus (Hagenides) rogersi expletus* Hobbs and Hart, 1959

31′ Cephalic process of first pleopod falling short of distal extremity of central projection (Fig. 54) .... *Procambarus (Hagenides) rogersi ochlocknensis* Hobbs, 1942

32(25′) Ischia of second and third pereiopods with hooks (Fig. 7) 33

32′ Ischia of third only or third and fourth pereiopods with hooks (Figs. 4, 5) 34

33(32) Terminal elements of first pleopod disposed at angle of about 90 degrees to axis of appendage (Fig. 41) .... *Cambarellus (Pandicambarus) blacki* Hobbs, 1980

33′ Terminal elements of first pleopod disposed at angle of no more than 60 degrees to axis of appendage (Fig. 42) .... *Cambarellus (Pandicambarus) schmitti* Hobbs, 1942

34(32′) First pleopod with distinct shoulder on cephalic surface remote from apex (Figs. 80-82) 35

34′ First pleopod lacking distinct shoulder on cephalic surface remote from apex (Figs. 57-79) 37

35(34) Cephalic process of first pleopod acute (Fig. 82) .... *Procambarus (Scapulicambarus) paeninsulanus* (Faxon, 1914)

35′ Cephalic process of first pleopod rounded (Figs. 80, 81) 36

36(35′) Areola with room for as many as 3 punctations across narrowest part .... *Procambarus (Scapulicambarus) okaloosae* Hobbs, 1942

36′ Areola with room for no more than 1 punctation in narrowest part .... *Procambarus (Scapulicambarus) clarkii* (Girard, 1852)

37(34′) Acumen as long as basal part of rostrum .... *Procambarus (Ortmannicus) youngi* Hobbs, 1942

37′ Acumen never as long as basal part of rostrum 38

38(37′) Mesial process of first pleopod long and sinuous (Fig. 57) .... *Procambarus (Leconticambarus) alleni* (Faxon, 1884)

38′ Mesial process never both long and sinuous (Figs. 58-79) 39

39(38′) Subapical setae of first pleopod almost or quite obscuring central projection in lateral aspect (Fig. 14) 40

39′ Subapical setae of first pleopod not obscuring most or all of central projection in lateral aspect 47

40(39) Cephalic process of first pleopod subspiculiform and directed distally or cephalodistally (Fig. 70) .... *Procambarus (Ortmannicus) seminolae* Hobbs, 1942

40′ Cephalic process of first pleopod acute, but never subspiculiform, and directed caudodistally (Figs. 68, 71-76) 41

41(40′) Areola no more than 3.5 times as long as broad .... *Procambarus (Ortmannicus) pictus* (Hobbs, 1940)

41′ Areola more than 3.5 times as long as broad 42

42(41′) Caudal process of first pleopod absent (Figs. 73, 74) 43

42′ Caudal process distinct although sometimes very small (Figs. 71, 72, 75, 76) 44

43(42) First pleopod tapering and caudally inclined distally (Fig. 73) .... *Procambarus (Ortmannicus) leonensis* Hobbs, 1942

43′ First pleopod not tapering, rounded, and not inclined distally (Fig. 74) .... *Procambarus (Ortmannicus) pycnogonopodus* Hobbs, 1942

44(42′) Cephalic process of first pleopod directed distally (Fig. 75); hooks on ischia of fourth pereiopods bituberculate (Fig. 6) .... *Procambarus (Ortmannicus) bivittatus* Hobbs, 1942

44′ Cephalic process of first pleopod directed strongly caudodistally (Figs. 71, 76); hooks on ischia of fourth pereiopods simple (Fig. 5) 45

45(44′) First pleopod with setiferous knob laterally (Fig. 71) .... *Procambarus (Ortmannicus) acutus acutus* (Girard, 1852)

45′ First pleopod without setiferous knob laterally 46

46(45′) Caudal process of first pleopod clearly defined; central projection subtriangular in lateral aspect (Fig. 76) .... *Procambarus (Ortmannicus) evermanni* (Faxon, 1890)

46′ Caudal process of first pleopod vestigial; central projection bladelike in lateral aspect (Fig. 72) .... *Procambarus (Ortmannicus) fallax* (Hagen, 1870)

47(39′) First pleopod with subapical setae confined to knoblike prominence at cephalolateral base of cephalic process 48

47′ First pleopod with subapical setae not restricted to knoblike prominence, forming sublinear series on cephalodistal margin of appendage 49

48(47′) Mesial process of first pleopod forming heavy subspatulate, subangular prominence (Figs. 16, 66) .... *Procambarus (Leconticambarus) kilbyi* (Hobbs, 1940)

48′ Mesial process of first pleopod acute, tapering from base (Figs. 17, 65) .... *Procambarus (Leconticambarus) hubbelli* (Hobbs, 1938)

49(46′) Hooks on ischia of third and fourth pereiopods (Fig. 5, 6) 50

49′ Hooks on ischia of third pereiopods only (Fig. 4) 56

50(49) Mesial surface of palm of chela barbate (Fig. 26) 51

50′ Mesial surface of palm of chela not barbate (Fig. 27) 54

51(50) Caudal process of first pleopod in form of sinuous, corneous ridge (Fig. 67) .... *Procambarus (Leconticambarus) shermani* Hobbs, 1942

51′ Caudal process of first pleopod not forming sinuous, corneous ridge (Figs. 58-64) 52

52(51′) Mesial process of first pleopod directed distally (Fig. 61) .... *Procambarus (Leconticambarus) pubischelae pubischelae* Hobbs, 1942

52′ Mesial process of first pleopod directed caudodistally 53

53(52′) Caudal process of first pleopod truncate (Fig. 60) .... *Procambarus (Leconticambarus) escambiensis* Hobbs, 1942

53′ Caudal process of first pleopod acute (Fig. 64) .... *Procambarus (Leconticambarus) capillatus* Hobbs, 1971

54(50′) Mesial process of first pleopod subspiculiform, curved, and directed distally (Fig. 62) .... *Procambarus (Leconticambarus) latipleurum* Hobbs, 1942

54′ Mesial process of first pleopod acute, straight, and directed caudodistally (Figs. 58, 59, 63, 64) 55

55(54′) Cephalic process of first pleopod curved with apex directed cephalodistally (Fig. 59) ....
.... *Procambarus (Leconticambarus) econfinae* Hobbs, 1942

55′ Cephalic process of first pleopod straight with apex directed caudodistally (Fig. 58) ....
..... *Procambarus (Leconticambarus) apalachicolae* Hobbs, 1942

56(49′) Palm of chela not barbate; caudal process of first pleopod directed cephalodistally (Fig. 63) ....
.... *Procambarus (Leconticambarus) rathbunae* (Hobbs, 1940)

56′ Palm of chela barbate; caudal process of first pleopod directed distally (Fig. 64) ....
.... *Procambarus (Leconticambarus) capillatus* Hobbs, 1971

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LITERATURE CITED

Bouchard, R. W. 1978. Taxonomy, ecology and phylogeny of the subgenus *Depressicambarus*, with the description of a new species from Florida and redescriptions of *Cambarus graysoni*, *Cambarus latimanus* and *Cambarus striatus* (Decapoda: Cambaridae). Bull. Ala. Mus. Nat. Hist. 3:27-60.

Cottle, T. J. 1863. On the two species of *Astacus* found in upper Canada. Canad. J. Indust., Sci. Arts, n.s., 45:216-219.

Faxon, W. 1884. Descriptions of new species of *Cambarus*, to which is added a synonymical list of the known species of *Cambarus* and *Astacus*. Proc. Amer. Acad. Arts Sci. 20:107-158.

________ 1890. Notes on North American crayfishes, family Astacidae. Proc. U.S. Nat. Mus. 12(785):619-634.

________ 1914. Notes on the crayfishes in the United States National Museum and the Museum of Comparative Zoology with descriptions of new species and subspecies to which is appended a catalogue of the known species and subspecies. Mem. Mus. Comp. Zool., Harvard Coll. 40(8):351-427.

Franz, R., and H. H. Hobbs, Jr. 1983. *Procambarus (Ortmannicus) leitheuseri*, new species, another troglobitic crayfish (Decapoda: Cambaridae) from peninsular Florida. Proc. Biol. Soc. Wash. 96(2):323-332.

________, and S. E. Franz. 1990. A review of the Florida crayfish fauna, with comments on nomenclature, distribution and conservation. Florida Scient. 53(4):288-298.

Girard, C. 1852. A revision of the North American Astaci, with observations on their habits and geographical distibution. Proc. Acad. Nat. Sci., Phila. 6:87-91.

Hagen, H. A. 1870. Monograph of the North American Astacidae. Illus. Cat. Mus. Comp. Zool., Harvard Coll. 3:109 pages.

Hay, W. P. 1899. Description of two new species of crayfish. Proc. U.S. Nat. Mus. 22(1187):121-123.

________. 1902. Observations on the crustacean fauna of Nickajack Cave, Tennessee, and vicinity. Proc. U.S. Nat. Mus. 25(1292):417-439.

Hobbs, H. H. Jr. 1938. A new crayfish from Florida. J. Wash. Acad. Sci. 28(2):61-65.

________. 1940. Seven new crayfishes of the genus *Cambarus* from Florida, with notes on other species. Proc. U.S. Nat. Mus. 89(3097):387-423.

________. 1941. Three new Florida crayfishes of the subgenus *Cambarus* (Decapoda, Astacidae). Amer. Mid. Nat. 26(1):110-121.

________. 1942. The crayfishes of Florida. Univ. Fla. Pub., Biol. Sci. Ser. 3(2): v + 179 pp.

________. 1953. A new crayfish of the genus *Procambarus* from Alabama and Florida (Decapoda, Astacidae). Proc. Biol. Soc. Wash. 66(22):173-178.

________. 1971. A New troglobitic crayfish from Florida. Quart. J. Fla. Acad. Sci. 34(2):114-124.

________. 1980. New dwarf crayfishes (Decapoda: Cambaridae) from Mexico and Florida. Proc. Biol. Soc. Wash. 93(1):194-207.

________. 1981. The crayfishes of Georgia. Smithsonian Contrib. Zool. 318:viii + 549 pp.

________ AND R. FRANZ. 1986. New troglobitic crayfish with comments on its relationship to epigean and other hypogean crayfishes of Florida. J. Crust. Biol. 6(3):509-519.

________ AND C. W. HART, JR. 1959. The freshwater decapod crustaceans of the Apalachicola drainage system in Florida, southern Alabama, and Georgia. Bull. Fla. St. Mus. 4(5):145-191.

________ AND D. S. LEE. 1976. A new troglobitic Crayfish (Decapoda, Cambaridae) from peninsular Florida. Proc. Biol. Soc. Wash. 89(32):383-391.

________ AND D. B. MEANS. 1972. Two new troglobitic crayfishes (Decapoda, Astacidae) from Florida. Proc. Biol. Soc. Wash. 84(46):393-409.

LECONTE, J. 1856. Descriptions of new species of *Astacus* from Georgia. Proc. Acad. Nat. Sci., Philadelphia 7:400-402.

LONNBERG, E. 1895. Cambarids from Florida. Bihang K. Svenska Vet.-Akad. Handl. 20, af.4(1):3-14.

RELYEA, K., AND B. SUTTON. 1975. A new troglobitic crayfish of the genus *Procambarus* from Florida (Decapoda, Astacidae). Tulane Stud. Zool. Bot. 19(1,2):8-16.

Florida Scient. 54(1):13-24. 1991.
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THE VASCULAR FLORA OF MCCARTY WOODS, HERNANDO COUNTY, FLORIDA

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Abstract: *McCarty Woods is a 2.2 ha tract located in the Brooksville Ridge region of west central Florida. It forms the western portion of the larger Chinsegut Hill and Robins Memorial Forest Preserve. The vegetation of McCarty Woods is southern mixed hardwoods dominated by* Quercus michauxii *(Basket Oak),* Q. virginiana *(Live Oak),* Q. nigra *(Water Oak),* Carpinus caroliniana *(Hornbeam),* Liquidambar styraciflua *(Sweetgum) and other hardwoods. The site has not burned since before 1932. The vascular flora of the site includes 82 species in 45 families. Twenty seven tree species occur on the site and approximately 38% of these are known to occur in southern mixed hardwood forests. McCarty Woods supports 55 species of understory shrubs, vines, and herbs, three of which are rare species currently listed as threatened or endangered.*

McCarty Woods is located in the Chinsegut Hill area of west-central Florida (28°35′N, 82°27′W), approximately six miles north of Brooksville in Hernando County (Fig. 1). This area is part of the Brooksville Ridge, a western outlier of the Central Highlands topographic region that extends down the middle of peninsular Florida to northern Glades County (White, 1970).

The Nature Conservancy, a national non-profit organization dedicated to the preservation of lands exemplary of diversity in the natural world, acquired McCarty Woods in 1965. It is a small (2.2 ha) tract supporting a diverse southern mixed hardwood forest. Although the McCarty Woods property itself is small, it forms the western portion of the much larger Chinsegut Hill and Robins Memorial Forest Preserve (ca. 160 ha) that also contains significant stands of old growth longleaf pine *(Pinus palustris)* and southern mixed hardwoods. The site is representative of the Brooksville Ridge region, an area characterized by rolling topography and underlain by Suwanee limestone of late Oligocene origin. The soils are calcareous, shallow, and poorly drained stony clay loams and sandy loams. In contrast to many sections of Florida, the area has significant topographic relief, and elevations in the Chinsegut Hill area range from 70′ to 274′ above sea level. The climate is warm temperate, with a mean annual temperature of 22°C and a mean annual precipitation of 147 cm. Further details concerning the geology, soils, and climate of the site can be found in Beckwith (1968).

McCarty Woods represents a particularly significant natural area in Florida for several reasons. As a representative example of the southern mixed hardwoods association, it supports a high diversity of plant species relative to other forest types in Florida. The southern mixed hardwoods is not only the most diverse, but is also one of the most variable in species composition of all forest associations found in Florida. Species composition and diversity vary

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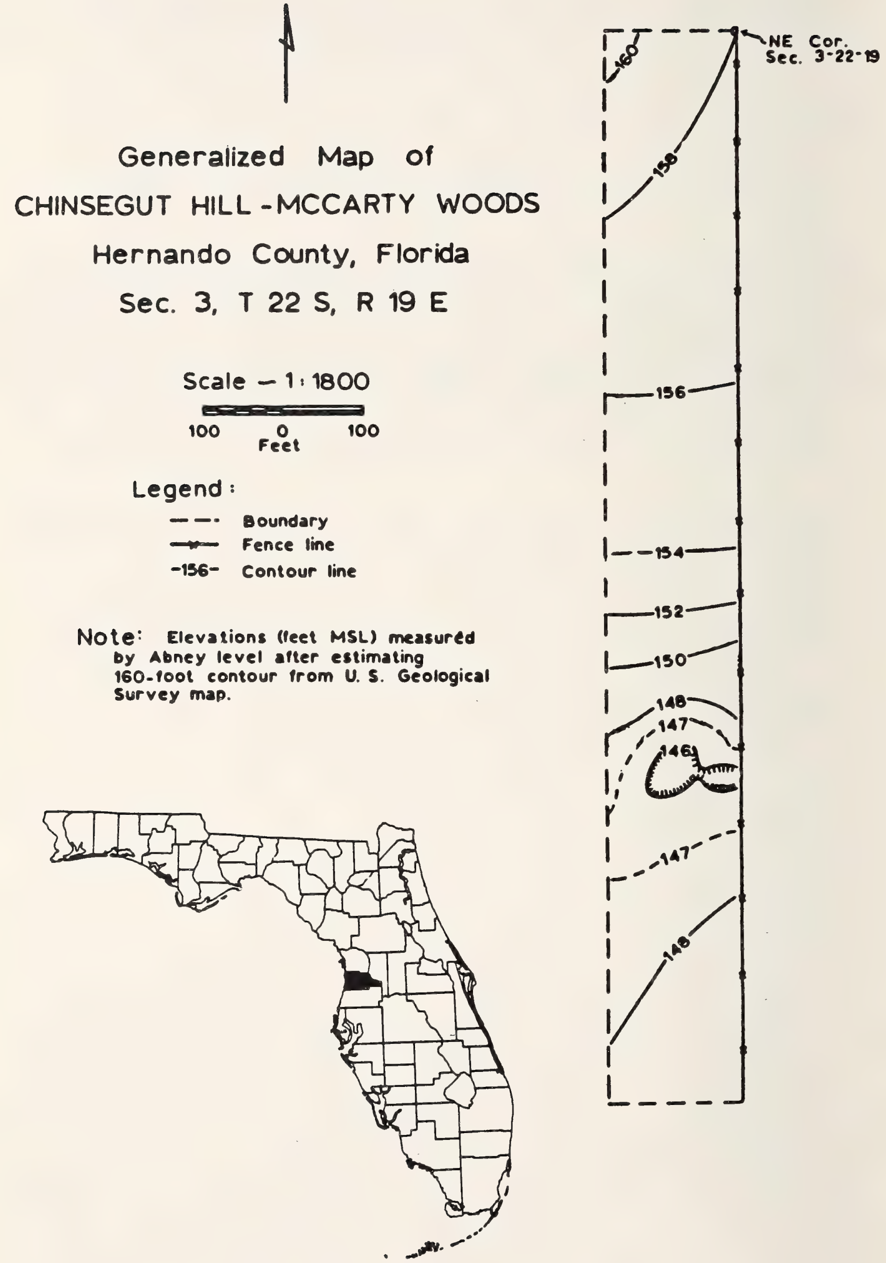

FIG. 1. Generalized map of McCarty Woods, Hernando County, Florida. (Modified after Bechwith [1968]).

considerably among sites depending on topography, soil fertility, hydrological regime, and geographical location (Monk, 1965, 1967, 1968). The McCarty Woods site is unique in that it is located at the southern limit of the distribution of this vegetation type and the southern limit of many of the temperate deciduous hardwood species.

In addition, a significant historical data base has accumulated on the vegetation and other ecological characteristics of this site. Beckwith (1968) described the soils, vegetation, and fauna of the site in 1965 and 1966, and also described its fire history and land-use history. Hartnett and Krofta (1989) described patterns of forest succession on the site from the time it was last burned in the early 1930's to 1985. They reconstructed this post-fire succession based on early site descriptions and data collected from vegetation sampling on the site in 1965 (Beckwith, 1968) and in 1985 (Hartnett and Krofta, 1989). To our knowledge, McCarty Woods represents the only forest in Florida in which successional dynamics have been documented directly by repeated measurements for many decades.

Because of the unique characteristics of this site, its status as a preserve of The Nature Conservancy, and recent increased research interest in the site, a more detailed description of its biota and abiotic characteristics would be valuable. This paper describes the vascular flora of McCarty Woods. The compilation of plant species that follows is based upon collections and observations made from 1985 through 1989. Beckwith (1968) compiled the first list of plant species for the site. His checklist included 21 dominant tree species and 52 species of understory shrubs, vines and herbs. The following list includes 82 species representing 45 vascular plant families. Voucher specimens for all taxa listed are deposited in the University of South Florida Herbarium. In the following list, family names are listed alphabetically within major groups to facilitate use. Within each family, genera and species are alphabetized. Nomenclature follows Wunderlin (1982).

PTERIDOPHYTES

Aspleniaceae
  Asplenium platyneuron (L.) BSP. Ebony Spleenwort.
Ophioglossaceae
  Botrychium biternatum (Sav.) Underw. Southern Grape Fern.
Polypodiaceae
  Plechuma dispersum (A.M. Evans) Price.
  Polypodium polypodioides (L.) Watt. Resurrection Fern.

GYMNOSPERMS

Cupressaceae
  Juniperus silicola (Small) Bailey. Southern Red Cedar.
Pinaceae
  Pinus elliottii Engelm. Slash Pine.
  Pinus palustris Mill. Longleaf Pine.

MONOCOTS

Amaryllidaceae
  Zephyranthes atamasco (L.) Herb. Atamasco-lily; Rain-lily.
Araceae
  Arisaema dracontium (L.) Schott. Green Dragon.
Arecaceae
  Sabal minor (Jacq.) Pers. Dwarf Palmetto.
  Sabal palmetto (Walt.) Lodd. ex Schultes. Cabbage Palm.
  Serenoa repens (Bartr.) Small. Saw Palmetto.
Bromeliaceae
  Tillandsia recurvata (L.) L. Ball-moss.
  Tillandsia setacea Sw. Wild pine.
  Tillandsia usneoides (L.) L. Spanish moss.
Orchidaceae
  Habenaria odontopetala Reichb. f.
  Habenaria repens Nutt.
Poacea
  Aristida stricta Michx. Wiregrass.
  Chasmanthium nitidum (Baldw.) Yates. Shiny Chasmanthium.
  Dichanthelium commutatum (Schult.) Gould.

DICOTS

Acanthaceae
  Elytraria caroliniensis (J. F. Gmel.) Pers.
  Justicia cooleyi Manachino & Leonard
  Ruellia caroliniensis (J. F. Gmel.) Steud. Wild Petunia.
Anacardiaceae
  Toxicodendron radicans (L.) Kuntze. Poison Ivy.
Asteraceae
  Baccharis glomeruliflora Pers. Groundsel Tree
  Bidens alba (L.) DC. Begger ticks.
  Bidens bipinnata L. Spanish Needles.
  Elephantopus caroliniensis Raeusch. Elephant's-Foot.
  Mikania scandens (L.) Willd.
  Verbesina virginica L. Frostweed.
Betulaceae
  Carpinus caroliniana Walt. Hornbeam; Bluebeech.
  Ostrya virginiana (Mill.) K. Koch. Hophornbeam.
Bignoniaceae
  Bignonia capreolata L. Cross-Vine.
Campanulaceae
  Lobelia homophylla F.W. Wimm.
Caprifoliaceae
  Lonicera sempervirens L. Coral Honeysuckle; Trumpet Honeysuckle.
  Viburnum dentatum L. Southern Arrowwood.

Cornaceae
    Cornus asperifolia Michx. Rough-leaf Cornel.
    Cornus florida L. Flowering Dogwood.
Ebenaceae
    Diospyros virginiana L. Persimmon
Ericaceae
    Vaccinium arboreum Marsh. Sparkleberry.
Fabaceae
    Desmodium paniculatum (L.) DC.
Fagaceae
    Quercus laurifolia Michx. Laurel Oak; Diamond Oak.
    Quercus michauxii Nutt. Basket Oak.
    Quercus nigra L. Water Oak.
    Quercus pumila Walt. Running Oak.
    Quercus virginiana Mill. Virginia Live Oak.
Hamamelidaceae
    Liquidambar styraciflua L. Sweetgum.
Hypericaceae
    Hypericum cistifolium Lam. St. John's-Wort.
Juglandaceae
    Carya glabra (Mill.) Sweet. Pignut Hickory.
Lamiaceae
    Hyptis mutabilis (A. Rich.) Briq. Musky Mint.
    Salvia lyrata L. Lyre-leaved Sage.
    Trichostema dichotomum L. Forked Blue-curls; Bastard Pennyroyal.
Lauraceae
    Cinnamonum camphora (L.) Nees & Eberm. Camphor-tree.
Loganiaceae
    Gelsemium sempervirens (L.) J. St. Hil. Yellow Jessamine.
Magnoliaceae
    Magnolia grandiflora L. Southern Magnolia.
Malvaceae
    Urena lobata L. Caesar-weed.
Moraceae
    Morus rubra L. Red Mulberry.
Oleaceae
    Fraxinus caroliniana Mill. Water Ash.
    Fraxinus pennsylvanica Marsh. Red Ash.
    Forestiera ligustrina (Michx.) Poir.
Polemoniaceae
    Phlox pilosa L. Downy Phlox.
Rosaceae
    Crataegus marshallii Eggl. Parsley Haw.
    Prunus caroliniana Ait. Carolina Laurel Cherry.
    Prunus serotina Ehrh. Wild Cherry.

Rubus trivialis Michx. Southern Dewberry.
Rubiaceae
Galium aparine L. Goose Grass.
Galium uniflorum Michx. Bedstraw.
Mitchella repens L. Partridge Berry; Twinberry.
Paederia foetida L. Skunk Vine.
Psychotria nervosa Sw. Wild Coffee.
Rutaceae
Citrus aurantium L. Sour Orange.
Sapindaceae
Sapindus saponaria L. False Dogwood; Southern Soapberry.
Sapotaceae
Bumelia lanuginosa (Michx.) Pers. Gum Bumelia.
Smilacaceae
Smilax bona-nox L. Greenbrier
Tiliaceae
Tilia caroliniana Mill. Carolina Basswood.
Ulmaceae
Celtis laevigata Willd. Hackberry.
Ulmus alata Michx. Winged Elm.
Ulmus americana L. American Elm.
Verbenaceae
Callicarpa americana L. Beautybush.
Violaceae
Viola affinis Le Conte.
Vitaceae
Vitis munsoniana Simpson. Southern Fox Grape.
Parthenocissus quinquefolia (L.) Planch. Virginia Creeper.

TABLE 1. Summary of the vascular flora of McCarty Woods, Hernando County, Florida.

	Families	Genera	Species
Pteridophytes	3	4	4
Gymnosperms	2	2	3
Monocots	6	9	13
Dicots	34	52	62
Total	45	67	82

DISCUSSION—A summary of the vascular flora of McCarty Woods is provided in Table 1. The four largest plant families on the site are Asteraceae (6 species), Fagaceae (5 species), Rubiaceae (5 species), and Rosaceae (4 species). It is clear, however that a large number of families are represented among the 82 species observed and most families are represented by only 1-3 species. Several of the herbaceous understory species are present as sparse populations with only a few individuals. Three herbaceous understory species, *Botrychium biternatum* (Sav.) Underw. (Ophioglossaceae), *Habenaria repens* Nutt. (Orchidaceae), and *Justicia cooleyi* Manachino & Leonard (Acanthaceae), are currently listed as threatened or endangered species (Official List of Endangered and Potentially Endangered Flora in Florida; Fla. Game and Freshwater Fish Commission, 1989).

Monk (1968) reported a minimum of 71 tree species from 30 families that may be encountered in southern mixed hardwood forests. The mean number of species per stand, however, is approximately 23. Thus, any given site typically contains only a subset of the tree species representative of this association and, as discussed above, this subset varies with topographical or edaphic characteristics or geographical location. The 27 tree species recorded at McCarty Woods represents 38% of the total number of tree species reported for southern mixed hardwoods and is higher than the average number occurring per stand for this association in Florida (Monk, 1965). The five dominant overstory tree species of McCarty Woods are *Quercus michauxii* (Fagaceae), *Q. virginiana* (Fagaceae), *Q. nigra* (Fagaceae), *Carpinus caroliniana* (Betulaceae), and *Liquidambar styraciflua* (Hamamelidaceae). *Quercus michauxii* and *Q. virginiana* together account for ca. 65% of the total tree canopy cover (Hartnett and Krofta, 1989). *Carpinus caroliniana* (Betulaceae) occurs at a higher density than any other tree species on the site (127 ha^{-1}) (Hartnett and Krofta, 1989), but its stature is much smaller than the dominant oaks and its total contribution to canopy cover is therefore much lower.

Monk (1968) reported that the mean contribution of evergreen species to the total tree flora of southern mixed hardwoods is 36.7%. McCarty Woods is somewhat atypical in this respect because only 17.8% of its species recorded here are evergreen. This low ratio of evergreen to deciduous species may be a result of the geographical location of McCarty Woods and/or its more mesic conditions relative to other southern mixed hardwood stands.

Overall, McCarty Woods supports a flora representative of the Brooksville Ridge region. The floristic composition of the site has changed significantly since the 1930's, however, as a result of fire suppression (Hartnett and Krofta, 1989). The overstory was orginally dominated by old growth longleaf pine, but it has undergone succession to a southern mixed hardwoods association, which is often described as the upland climax vegetation type over most of the southeastern coastal plain (Quarterman and Keever, 1962; Monk, 1965, 1967). Hartnett and Krofta (1989) have described the dynamics of successional replacements of pine by hardwoods and more recent successional changes among the hardwoods on this site. There are significant dissimilarities in the lists of herbs, vines, and shrubs reported for this site by Beckwith (1968) and those reported here. This suggests that successional changes in tree species composition and relative abundances that have occurred on this site over the past several decades have been accompanied by changes in the understory floristic composition as well.

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LITERATURE CITED

BECKWITH, S. L. 1968. Chinsegut Hill-McCarty Woods, Hernando County Florida. Quart. J. Florida Acad. Sci. 30:250-268.

HARTNETT, D. C. AND D. M. KROFTA. 1989. Fifty-five years of post-fire succession in a southern mixed hardwood forest. Bull. Torrey Bot. Club 116:107-113.

MONK, C. D. 1965. Southern mixed hardwood forests of northcentral Florida. Ecol. Mongr. 35:335-354.

_________. 1967. Tree species diversity in the eastern deciduous forest with particular reference to north central Florida. Amer. Nat. 101:173-187.

_________. 1968. Successional and environmental relationships of the forest vegetation of north central Florida. Amer. Midl. Naturalist 79:441-457.

QUARTERMAN, E. AND C. KEEVER. 1962. Southern mixed hardwood forest: Climax in the southeastern coastal plain, U.S.A. Ecol. Monogr. 32:167-185.

WHITE, W. A. 1970. The geomorphology of the Florida Peninsula. Geological Bull. 51. Florida Dept. Nat. Resources, Tallahassee.

WUNDERLIN, R. P. 1982. Guide to the Vascular Plants of Central Florida. Univ. Presses of Florida, Gainesville.

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WETLAND IMPOUNDMENTS OF[1] EAST-CENTRAL FLORIDA

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ABSTRACT: *Data on the physical characteristics, vegetation, geographic location, and areal coverage of the coastal impoundments in east-central Florida are presented. There are 195 impoundments in the region, covering over 16,000 ha of coastal wetlands. Vegetation in the impoundments is diverse; mangroves predominate in the southern impoundments while herbaceous halophytes predominate in the northern ones. Approximately 3,600 ha of these impoundments are unvegetated, whereas mangroves cover close to 4,000 ha and other halophytic species 4,300 ha. Management of the impoundments varies from none to complex schemes that address not only mosquito control problems but also natural resource and habitat quality interests. Nearly 4,500 ha of impounded wetlands in the Merritt Island National Wildlife Refuge are flooded year-round for waterfowl management, whereas 2,857 ha are under Rotational Impoundment Management (RIM). Present and future management strategies for these impoundments are discussed.*

SINCE the 1930s, control of salt marsh mosquitoes, be it by liberal use of insecticides, by marsh filling, or by ditching and diking, have been applauded by the general public and by local and state health officials, and has been in great part responsible for Florida's growth. The development of tourism and retirement communities as important components of Florida's economy, the growing population of the state (and its concentration in coastal areas), and the high desirability of waterfront property have created additional and unprecedented demands for the control of the hordes of mosquitoes that breed in the state's salt marshes.

However, research during the last three decades has uncovered the critical role played by salt marshes and mangrove forests in the dynamics of their associated estuaries, and on the biology of the many organisms that directly or indirectly depend upon wetlands and estuaries during all or part of their life cycles. With acquisition of this knowledge came strong concerns about possible detrimental effects of practices such as ditching and impounding large expanses of coastal wetlands for mosquito control. This concern, in turn, stimulated new research, particularly in *Spartina* and *Juncus* marshes, directly aimed at identifying problem areas and at devising management programs that would be more ecologically sound, as well as effective in controlling mosquito populations. As a result, innovative management schemes for salt marsh mosquito control such as Open Marsh Water Management (Shisler and Jobbins, 1977) were developed for use in grass and rush marshes.

In many areas of Florida, however, the salt marsh mosquito control problem is quite different than in the typical east coast *Spartina* marsh. First, because of peculiar tidal effects, many Florida marshes consist primarily of high marsh (Provost, 1976), which is the prime breeding area for salt marsh mosquitoes. Second, in many areas of the state, tidal energy cannot be relied upon to circulate water through ditches and other structures because these areas do not experience regular lunar tidal cycles. Instead, they are exposed to varying degrees of wind-driven "tides" and to fluctuating water levels depending upon rainfall and seasonal sea level changes. Third, whereas the mosquito control problem in grassy salt marshes is straightforward, mangrove forests in peninsular Florida are complex and require a totally different management approach.

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Impoundment History—Impoundments have been used in the past for a wide variety of purposes including waterfowl management (Hardin, 1987), water storage (Baxter, 1977), flood control (Rutter and Engstrom, 1964), agriculture (Tompkins, 1987), sewage treatment (Carlson, 1983), aquaculture (Bardach et al., 1972), energy production (Mermel, 1976), mosquito control (Provost, 1977), and recreation (Mermel, 1976). A mosquito control impoundment is a marsh or mangrove forest that has been diked to allow control of water levels. Some dikes surround the entire marsh, whereas others stop at the upland edge. A perimeter ditch, created by removal of material for dike construction, parallels the dike on the inside of the marsh. Impoundments have a number of associated water control structures. Pumps (electric or diesel, permanent or portable) are used to flood the impoundments, culverts with gates of different types usually connect the marsh with the lagoon, and internal ditches, spillways, and other structures are often part of the impoundment design. These structures are described in detail by Provost (1974a, 1977), and by Rey and Kain (1990). Some impoundments, however, do not have any connecting structures and remain isolated from the lagoon during the entire year. Mosquito control is obtained when an impoundment is flooded during the mosquito producing season because salt marsh mosquitoes will not oviposit upon standing water or overly moist soil.

A large proportion of the salt marshes and mangrove forests bordering the Indian River lagoon in east-central Florida, have been impounded for mosquito control. Wetland impoundment is popular with mosquito control agencies because the technique is effective in controlling the salt marsh mosquitoes *Aedes taeniorhynchus* (Wiedemann) and *A. sollicitans* (Walker) without the use of potentially harmful pesticides, and is relatively cost-effective.

The first Florida impoundment for mosquito control was built in the late 1930s (Hull et al., 1939), but the project was abandoned because of excessive water losses (Clements and Rogers, 1964). In the 1950s, impoundments were shown to be effective mosquito control tools in the middle Atlantic states (Chapman and Ferrigno, 1956; Darsie and Springer, 1957), and this provided additional incentives for incorporation of the technique into the Florida mosquito control arsenal. The first impoundments along the Indian River were built in Brevard County in 1954, and other counties soon followed suit. By 1970, most of the present-day impoundments had been completed (Provost, 1977).

Impoundment Management—The peak mosquito producing season along the Indian River runs approximately from May to October. During this period, most impoundments are kept flooded. Although only a thin film of water is required to prevent oviposition by the salt marsh mosquitoes, impoundments are usually flooded from 15 to 50 cm above the surface to compensate for evaporation, water leakage, and marsh irregularities. Management during the rest of the year varies; some impoundments are left closed and flooded the entire year, whereas others are reconnected to the lagoon in the fall by opening culverts or other water control structures. The present trend is to close and flood the impoundments after the first heavy rainfall event in late spring and to reopen at high tide after the seasonal rise in lagoon waters in the fall. This schedule avoids releasing large volumes of poor quality impoundment water into the lagoon, as lagoon water first flows into the impoundment and mixes with impoundment water before flowing back into the lagoon at low tide. This schedule also avoids stranding aquatic organisms in the very poor quality bottom layer of water of the perimeter ditches, a situation that sometimes causes large fish kills in the fall. Impoundments managed in this manner are said to be under Rotational Impoundment Management (RIM; Carlson and Carroll, 1985). A great deal of effort is presently being spent in increasing the number of impoundments under RIM and in increasing the tidal connections (culverts) between impoundments and the lagoon. Use of culverts with flapgate risers that allow adjustment of flooding elevations is also being encouraged to avoid damaging the marsh vegetation. Flapgates also allow lagoon waters to flow into impoundments when water levels in the lagoon are higher than in the impoundments, thus improving impoundment water quality during the closed period. This, however, does not happen often during the closed period in summer because during this season lagoon water levels are usually at their lowest (Provost, 1974b, 1976).

Mosquito Control Impoundments in East-Central Florida—Below we present summary data on the physical characteristics, vegetation and geographic location of the coastal impoundments in east-central Florida and discuss past and present trends in management of these areas. The data are the result of an impoundment-by-impoundment inventory developed under the auspices of the St. Johns River Water Management District (Rey and Kain, 1990). Maps of each impoundment were generated via computer by scanning existing maps or aerial photographs. A copy of the maps and a form for entering the physical characteristics and water control structures of each impoundment were sent to each agency responsible for managing impoundments (mosquito control districts, U.S. Fish and Wildlife Service, etc.). Vegetation cover for each impoundment was estimated using a variety of techniques, including ground surveys, aerial photographs, or by direct observation from the air; thus, these data are of varying degrees of accuracy. This information was then compiled and the pertinent structures and vegetation data incorporated into each of the maps and into a final data sheet for each impoundment. Summary tables and figures were created with the RS/1

TABLE 1. Summary data for the salt marsh impoundments of east-central Florida.

	Location[a]							
	FLAG.	VOL.	BREV.	MINWR	I.RIV.	ST.LUC.	MART.	TOTAL
Number.	1	5	23	79	33	43	8	195
Hectares	122	639	1429	10904	1121	1901	253	16369
% of Total	0.7	3.9	8.7	66.8	6.9	11.4	1.6	100.0
Public	0	194	852	10904	168	1107	0	13224
Private	122	446	577	0	954	794	253	3144

[a] FLAG. = Flagler Co., VOL. = Volusia Co., BREV. = Brevard Co., MINWR = Merritt Island National Wildlife Refuge, I.RIV. = Indian River County, ST.LUC. = St. Lucie Co., MART = Martin Co.

Data Analysis System (BBN Software, Cambridge, Massachusetts). All maps and data sheet information are stored in magnetic media and will be updated yearly.

There are 195 impoundments along the east central coast of Florida, covering a total of 16,368 ha of tidal marshes and mangrove forests. The largest block of impoundments is located in the Merritt Island National Wildlife Refuge (MINWR) followed by St. Lucie Co., Brevard Co., and Indian River Co. (Table 1). Although most of these impoundments were constructed for mosquito control, many of the MINWR ones are now managed for waterfowl habitat. Excluding the impoundments in the MINWR, 58% of the impoundment area of the lagoon is under private ownership (Fig. 1). Private ownership often creates problems in implementing management plans, as owner permission is generally required, and many owners are hesitant to allow

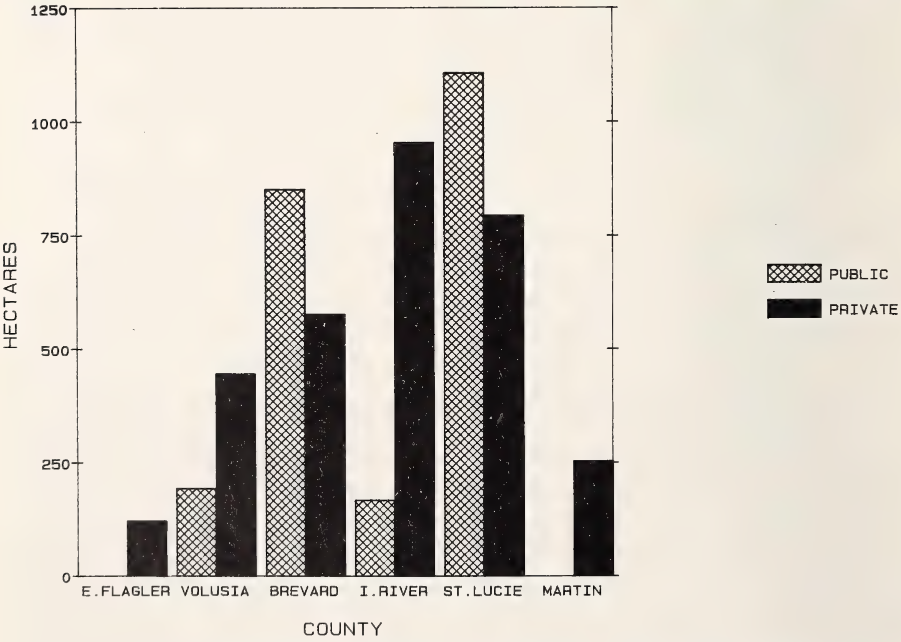

FIG. 1. Coastal impoundment ownership in east-central Florida, solid, private; cross-hatched, public.

TABLE 2. Vegetation cover of the Indian River impoundments (hectares). Row sums may not be exact due to rounding errors.

	Location[a]							
	FLAG.	VOL.	BREV.	MINWR	I.RIV.	ST.LUC.	MART.	TOTAL
Rhizophora mangle	0	0	0	0	205	975	116	1296
Avicennia germinans	0	67	23	353	13	208	47	710
Laguncularia racemosa	0	0	4	48	3	114	27	195
Mixed Mangrove	0	0	249	930	389	130	26	1724
Batis maritima	0	0	0	0	1	8	1	10
Salicornia spp.	0	0	0	0	0	2	0	2
Spartina spp.	0	56	0	1491	0	1	0	1458
Juncus spp.	49	60	48	39	0	0	0	195
Borrichia frutescens	0	11	1	59	0	1	0	71
Distichlis spicata	0	15	616	1100	19	0	0	1749
Mixed halophytes	49	296	2	223	143	89	0	802
Upland species	24	6	188	2111	6	7	19	2361
Typha spp.	0	33	182	1443	5	85	0	1748
Exotics	0	2	34	129	1	8	11	185
Mangrove fern	0	0	11	8	0	0	6	26
Marsh shrubs	0	5	0	0	0	0	0	5
Salix spp.	0	0	0	120	0	0	0	120
Emergent vegetation	0	0	0	6	0	0	0	6
Hardwood swamp	0	0	0	12	0	0	0	12
Unvegetated	0	89	72	2833	337	274	0	3605
Total mangroves	0	67	276	1332	609	1426	216	3926
Total halophytes	97	438	656	2911	163	100	1	4376

[a] FLAG. = Flagler Co., VOL. = Volusia Co., BREV. = Brevard Co., MINWR = Merritt Island National Wildlife Refuge, I.RIV. = Indian River County, ST.LUC. = St. Lucie Co., MART = Martin Co.

management of their property for fear that this may limit their options for future development.

Mangroves predominate in the southern impoundments, whereas herbaceous halophytes such as *Spartina* spp., *Batis maritima*, *Salicornia* spp., and *Distichlis spicata* predominate from Brevard County north (Table 2). The greatest proportion of mangroves in Brevard Co. (90%), MINWR (70%), and Indian River Co. (64%) occur in mixed forests. Pure stands of red mangroves are only found south of Brevard Co., where they make up 34% of the mangrove cover in Indian River Co., 68% in St. Lucie, and 54% in Martin. A significant proportion (19%) of the vegetation in MINWR impoundments consists of "upland species", and *Typha* spp. cover an additional 13% of the impounded acreage. Note that some species may contribute to more than one category in Table 2; for example, *Batis maritima* and *Salicornia* spp. are common herbaceous halophytes in Indian River and St. Lucie Co. impoundments, but they usually occur in mixed stands, therefore most of their coverage is recorded under "mixed halophytes".

A total of 50 pumps and 540 culverts presently service the east central Florida impoundments. St. Lucie County has the greatest number of culverts (205) as a result of an aggressive marsh management program by the county's mosquito control district (Fig. 2). They are followed by MINWR (171), Brevard County (88), and Indian River County (48).

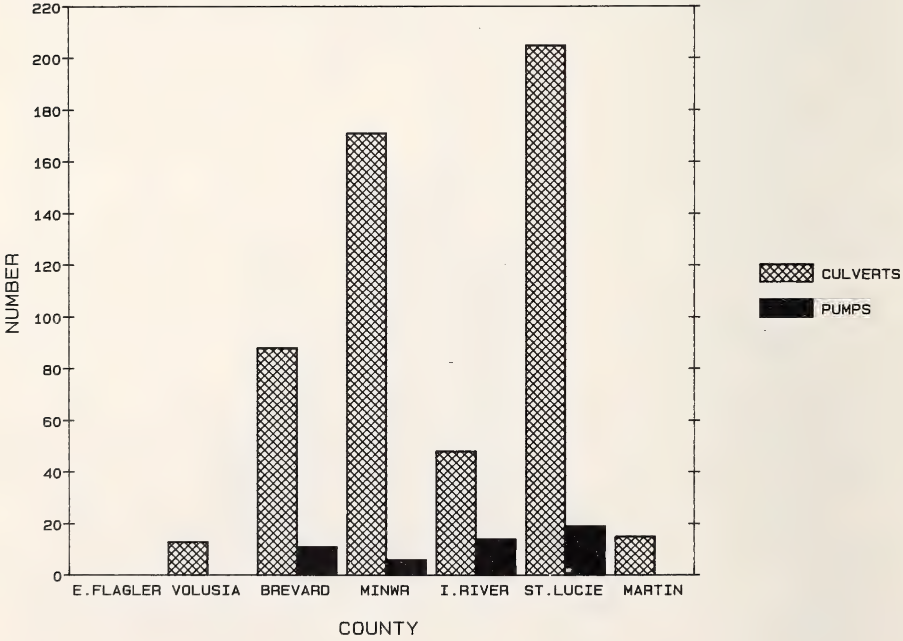

FIG. 2. Culverts (cross-hatched) and pumps (solid) in use in the mosquito control impoundments.

Over 40% (4,494 ha) of the impounded acreage in the MINWR is flooded the entire year for waterfowl management purposes (Table 3). RIM is the most common management strategy in Brevard (1,037 ha), St. Lucie (1,371 ha), and Indian River (448 ha) counties. Over 70% of the impoundment acreage in the former two counties are under this protocol, whereas in Indian River 40% are under RIM. The lower percentage in the latter is in part a reflection of the higher proportion of privately owned impoundments in Indian River Co. than in Brevard and St. Lucie (Fig. 1). In Flagler County, all impoundments are open (122 ha), whereas Martin County has 12% of its impoundments closed (31 ha), 27% open all year (69 ha), and 61% with breached dikes (154 ha).

TABLE 3. Impoundment management regimes (hectares). Closed(A) = closed all year; Closed(B) = closed, occasionally opened.

	Location[a]							
	FLAG.	VOL.	BREV.	MINWR	I.RIV.	ST.LUC.	MART.	TOTAL
Closed(A)	0	17	160	1839	252	130	31	2430
Closed(B)	0	0	115	0	0	0	0	115
Flooded all year	0	0	4	4494	30	19	0	4548
RIM	0	0	1037	0	448	1371	0	2857
Seasonally flooded	0	0	97	3461	155	0	0	3714
Ditched, seas. flood.	0	0	0	18	0	0	0	18
OMWM	0	137	0	869	7	0	0	1013
Open	122	484	3	0	91	377	69	1146
Breached	0	0	13	0	117	3	154	286
Restored	0	0	0	221	0	0	0	221
Sewage treatment	0	0	0	0	21	0	0	21
Total	122	638	1429	10903	1122	1900	254	16369

[a] FLAG. = Flagler Co., VOL. = Volusia Co., BREV. = Brevard Co., MINWR = Merritt Island National Wildlife Refuge, I.RIV. = Indian River County, ST.LUC. = St. Lucie Co., MART = Martin Co.

Future Trends—Improved management of the east central Florida impoundments will continue to be a high priority item for local scientists, resource managers, environmental regulatory agencies, and mosquito control personnel. Although there will continue to be a strong push for enhancing lagoon-impoundment connections, particularly in impoundments that are totally isolated (i.e., no culverts), the emphasis is now shifting from managing individual impoundments to managing groups of impoundments as 'blocks' so that complementary management strategies can be applied to different members of the block. In other words, rather than applying identical management to each impoundment, management aimed at enhancing different components of the marsh-estuary system (e.g., fish, birds, water quality, vegetation, etc.) could be applied to different impoundments within a block. The ultimate goal, however, is to develop regional plans that include the entire lagoon, as only in this way can we assure that the multiple functions of natural salt marshes and mangrove forests are properly addressed in our management efforts, and that this is done in a geographically equitable manner.

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LITERATURE CITED

Baxter, R. M. 1977. Ecological effects of dams and impoundments. Ann. Rev. Ecol. Syst. 8:255-283.

Bardach, J. E., J. H. Ryther, and W. O. McLarney. 1972. Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. Wiley-Interscience, New York, N.Y.

Carlson, D. B. 1983. The use of salt-marsh mosquito control impoundments as wastewater retention areas. Mosquito News 43:1-6.

_________ and J. D. Carroll, Jr. 1985. Developing and implementing impoundment management methods benefiting mosquito control, fish, and wildlife: A two year progress report about the Technical Subcommittee on Mosquito Impoundments. J. FL Anti-Mosquito Assoc. 56:24-32.

Chapman, H. C. and F. Ferrigno. 1956. A three-year study of mosquito breeding in natural and impounded salt marsh areas of New Jersey. Proc. N.J. Mosq. Exterm. Assoc. 43:48-64.

Clements, B. W., Jr. and A. J. Rogers. 1964. Studies of impounding for the control of salt-marsh mosquitoes in Florida, 1958-1963. Mosquito News 24:265-276.

Darsie, R. F. and P. F. Springer. 1957. Three-year investigation of mosquito breeding in natural and impounded tidal marshes in Delaware. Univ. Delaware Ag. Exp. Sta. Bull. 320.

Hull, J. B., W. E. Dove, and N. G. Platts. 1939. Experimental diking for control of sand fly, and mosquito breeding in Florida salt water marshes. J. Econ. Ent. 36:405-409.

Hardin, D. 1987. An evaluation of impoundments and ponds created for waterfowl in Delaware. Pp. 120-126. *In:* DeVoe, M. R. and D. S. Baugham (eds.). South Carolina Coastal Wetlands Impoundments: Ecological Characterization, Management, Status, and Use. Vol. II. Pub. # SC-SG-TR-86-2, S.C. Sea Grant Consortium, Charleston.

Mermel, T. W. 1976. International Activity in dam construction. Int. Water. Power Dam Constr. 28:66-69.

Provost, M. P. 1974a. Salt marsh management in Florida. Proc. Tall Timbers Conf. on Ecol. Animal Control by Habitat Management 1973:5-17.

_________. 1974b. Mean high water mark and use of tidelands in Florida. Florida Scient. 36:50-65.

_________. 1976. Tidal datum planes circumscribing salt marshes. Bull. Mar. Sci. 26:558-563.

_________. 1977. Source reduction in salt-marsh mosquito control: Past and Future. Mosquito News 37:689-698.

Rey, J. R. and T. Kain. 1990. A Guide to the Salt Marsh Impoundments of Florida. Fl. Medical Ent. Lab. Pub. Vero Beach, FL.

Rutter, E. J. and L. R. Engstrom. 1964. Hydrology of flood control. Part III. Reservoir regulation. Pp. 60-97. *In:* Chow, V. T. (ed.). Handbook of Applied Hydrology, McGraw-Hill, New York, N.Y.

Shisler, J. K. and D. M. Jobbins. 1977. Salt marsh productivity as affected by the selective ditching technique, Open Marsh Water Management. Mosquito News 37:631-636.

Tompkins, M. E. 1987. Historical review of South Carolina's impoundments. Pp. 3-11. *In:* DeVoe, M. R. and D. S. Baugham (eds.). South Carolina Coastal Wetlands Impoundments: Ecological Characterization, Management, Status, and Use. Vol II. Pub. # SC-SG-TR-86-2, S.C. Sea Grant Consortium, Charleston.

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CHRYSOPHYCEAE (MALLOMONADACEAE AND PARAPHYSOMONADACEAE) FROM FLORIDA. III. ADDITIONS TO THE FLORA

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Abstract: *Forty-two species, varieties and forms of the silica-scaled Chrysophycean families Mallomonadaceae and Paraphysomonadaceae are reported from central and southern Florida. Identifications were based on electron microscopical details of siliceous scales and bristles. Five taxa not previously reported for the U.S. are included, including one new to North America.*

Ultrastructural studies on scale-bearing Chrysophycean flora from the southeastern U.S. are few. Wujek (1983, 1984), Wujek and Gardiner (1985) and Wujek and Bland (1988) reported findings from Florida. Their localities are primarily from the central and west coast regions. They recorded 25 species and varieties of scale-bearing Chrysophyceae, five of which were new to science.

The observations reported here were made during studies designed to investigate by electron microscopy, the scale-bearing Chrysophyceae from central and southern Florida. Examination of samples resulted in the identification of 42 species, including five varieties and five forms of chrysophytes, i.e., members of the families Mallomonadaceae Diesing and Paraphysomonadaceae Preisig and Hibberd.

Methods and Materials—Freshly collected phytoplankton samples were prepared for electron microscopy according to procedures described by Wujek (1983, 1984).

Results and Discussion—A listing of all taxa and their localities observed appear in Table 1. An asterisk before the name indicates a taxon first reported for the contiguous U.S. Only those that are newly reported for the U.S. and/or Florida are described below.

**Mallomonas bronchartiana* Compere (Fig. 1). This species has been reported only from tropical freshwater locations: Lake Chad (Compere, 1974) and Malaysia (Dürrschmidt and Croome, 1985). This is the first report of this species for North America.

M. canina Kristiansen (Fig. 2). Recently reported for North America from Michigan (Wujek and Igoe, 1989), its presence in Lake Annie represents its southern most collection in North America.

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*All of the following electron micrographs are scales and bristles and are not the individual organisms.

TABLE 1. The distribution of 42 species of scaled chrysophytes in thirteen locations in central and southern Florida.

TAXON	Location(s)[a]												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Mallomonas akrokomas Ruttner											*		
M. bronchartiana Compere				*									
M. canina Kristiansen									*				
M. caudata Krieger		*			*	*			*		*	*	*
M. crassisquama (Asmund) Fott	*												
M. cristata Dürrschmidt				*									
M. cyathellata var. *kenyana* Wujek & Asmund		*			*					*	*		
M. favosa f. *favosa* Nicholls				*									
M. guttata Wujek				*									
M. hamata Asmund									*				
M. mangofera Harris & Bradley					*								
M. mangofera var. *foveata* Dürrschmidt					*								
M. elliptica Matvienko		*		*	*								
M. multiunca Asmund					*	*	*						*
M. ouradion (Harris & Bradley) Harris				*	*								
M. papillosa var. *papillosa* Harris & Bradley				*	*								
M. parvula var. *nichollsii* Wujek & Bland		*											
M. portae-ferreae Peterfi & Asmund	*									*	*		
M. pseudocoronata Prescott		*											
M. paludosa Fott				*	*	*			*				
M. pillula f. *pillula* Harris					*								
M. pumilo var. *pumilo* Harris & Bradley emend. Asmund, Cronberg & Dürrschmidt		*											
M. sphagniphila Nicholls				*									
M. tonsurata Teiling emend. Krieger		*		*									
Synura curtispina Asmund	*			*									
S. echinulata Korshikov		*		*	*				*		*	*	*
S. mollispina (Petersen & Hansen) Peterfi & Momeu				*					*				
S. petersenii Korshikov		*		*					*	*	*		
S. petersenii f. *kufferathi* Petersen & Hansen					*								
S. sphagnicola Korshikov					*	*	*		*				
S. spinosa f. *spinosa* Korshikov		*				*				*	*		
S. spinosa f. *longispina* Petersen & Hansen		*		*	*								
S. uvella Stein				*	*	*	*			*	*		
Paraphysomonas amphiplana Wujek					*								
P. imperforata Lucas	*	*	*		*								
P. stephanolepis Preisig & Hibberd				*									
P. undulata Preisig & Hibberd			*										
P. vestita (Stokes) de Saedeleer	*	*		*	*	*					*		
Spiniferomonas alata Takahashi									*				
S. bourrelleyi Takahashi						*	*						
S. trioralis Takahashi											*	*	
Chrysodidymus synuroides Prowse				*	*		*						

[a] 1. Drainage canal, south end of Moore Haven draining into Caloosohatchee River, Glades Co.
2. Ditch six miles north of Belle Glade along Hwy 441, Palm Beach Co.
3. Near site 2, but major canal paralleling Hwy 441, Palm Beach Co.
4. "Alligator pond", Highlands Hammock, Highlands Co.
5. "Fern Trail", Highlands Hammock, Highlands Co.

TABLE 1.—Continued

6. Sink hole, Archbold Biological Station, Highlands Co.
7. Sink hole, (west side), ABS, Highlands Co.
8. Lake Placid, north end along Price Tract, Highlands Co.
9. Lake Annie (north end), Highlands Co.
10. Caloosahatchee River (Oxbow Twp.), Lee Co.
11. Hickey Creek, Lee Co.
12. J. N. Darling Wildlife Refuge (across from first observation tower), Sanibel Island, Lee Co.
13. Hwy 72, 14 miles west of junction Hwy 72 and 70, De Soto Co.

**M. favosa* var. *favosa* Nicholls (Fig. 3). A species that has been collected both in the northern temperate regions (Nicholls, 1984) and in Malaysia and tropical Australia (Durrschmidt and Croome, 1985). Scales of this organism represent the first report for the U.S.

M. hamata Asmund (Fig. 4). Previous reports for the U.S. are from fossil sediments (Smol et al., 1984a, 1984b) in the Adirondack region (New York) and from Michigan (Wujek, 1986).

M. multiunca Asmund (Fig. 5). One of the first *Mallomonas* species to be observed with the electron microscope (Asmund, 1959), Asmund and Kristiansen (1986) report its most recent distribution.

M. ouradion Harris and Bradley (Fig. 6). Recently reported for the U.S. (Wujek, 1986).

M. paludosa Fott (Fig. 7). This species has been reported for northern Michigan (Wawrzyniak and Andersen, 1985) and our specimens from four Florida sites represents the second report for the U.S.

M. papillosa var. *papillosa* Harris and Bradley emend. Harris (Fig. 8). This species has a wide distribution (Asmund and Kristiansen, 1986).

M. pillula f. *pillula* Harris (Fig. 9). Other reports of this species for the U.S. are from Iowa (Wee, 1982) and Michigan (Wujek, 1986).

**M. pumilo* var. *pumilo* Harris and Bradley emend Asmund, Cronberg and Dürrschmidt (Fig. 10). The scales of the site 5 material exhibit the regular arrangement of dots on the anterior flanges and submarginal ribs. This variety was recently reported for North America (Canada: Ontario) by Nicholls (1988).

**M. sphagniphila* Nicholls (Fig. 11). A recently described species from Ontario, Canada (Nicholls, 1987). This is the first collection from the U.S.

Synura mollispina (Petersen and Hansen) Peterfi and Momeu (Fig. 12). Wee (1982) suggests that the variety of scale types and partial secondary layer on the reticulum are distinctive enough for this species to be identified using phase contrast microscopy.

S. petersenii f. *kufferathi* Petersen and Hansen (Fig. 13). Loose scales only (no whole cells) were observed in the site "Fern Trail" sample.

S. spinosa f. *spinosa* Korschikov (Fig. 14).

S. spinosa f. *longispina* Petersen and Hansen (Fig. 15). Distinguished from f. *spinosa* on the basis of the size of the spine. Our observation of scales from Florida represents its third report for North America.

S. uvella Stein (Fig. 16). Widely distributed in 13 countries, it has been reported previously 11 times for the United States (Wawrzyniak and Andersen, 1985).

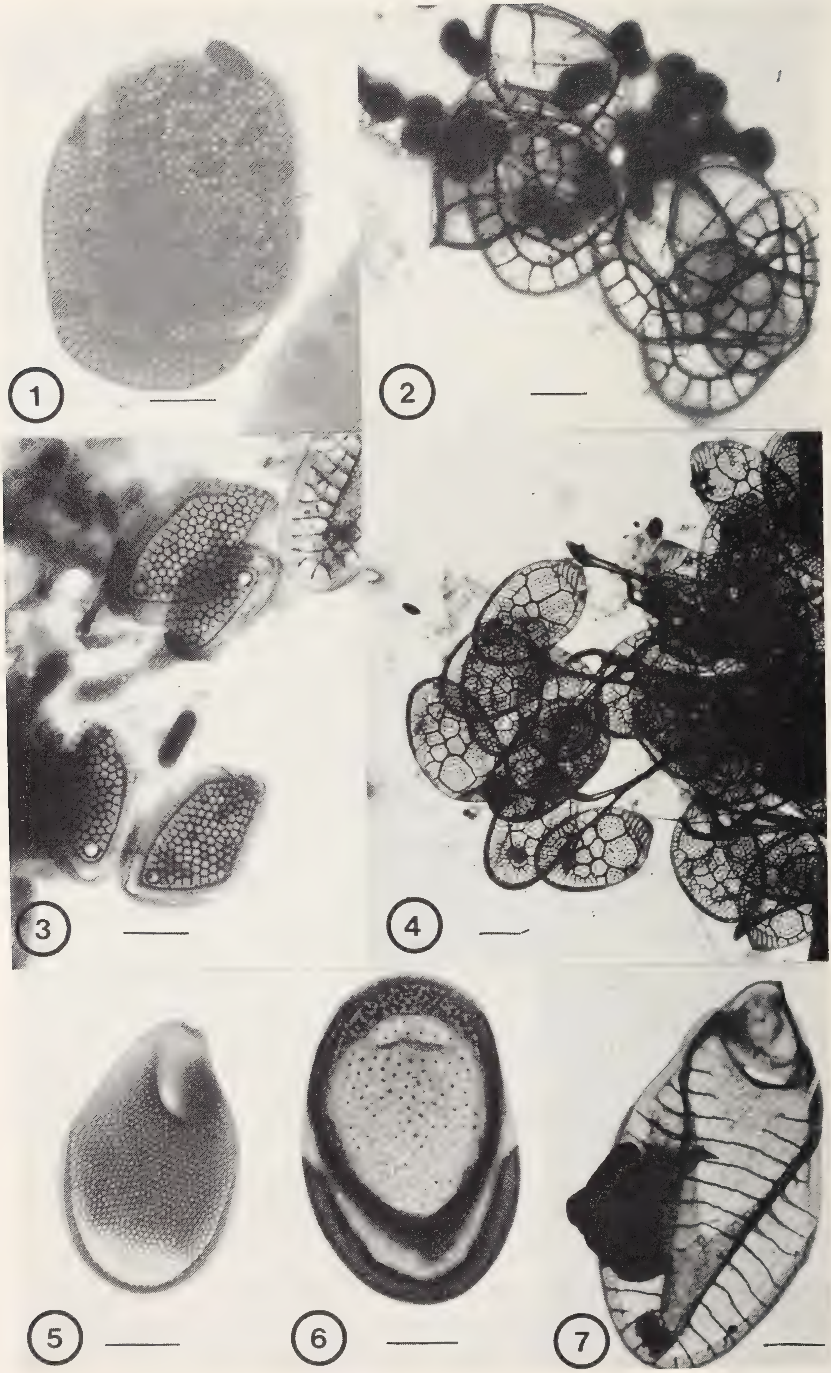


FIG. 1. *Mallomonas bronchartiana*. FIG. 2. *M. canina*. FIG. 3. *M. canina*. FIG. 4. *M. hamata*. FIG. 5. *M. multiunca*. FIG. 6. *M. ouradion*. FIG. 7. *M. paludosa*. Scale bar = 1 μm.

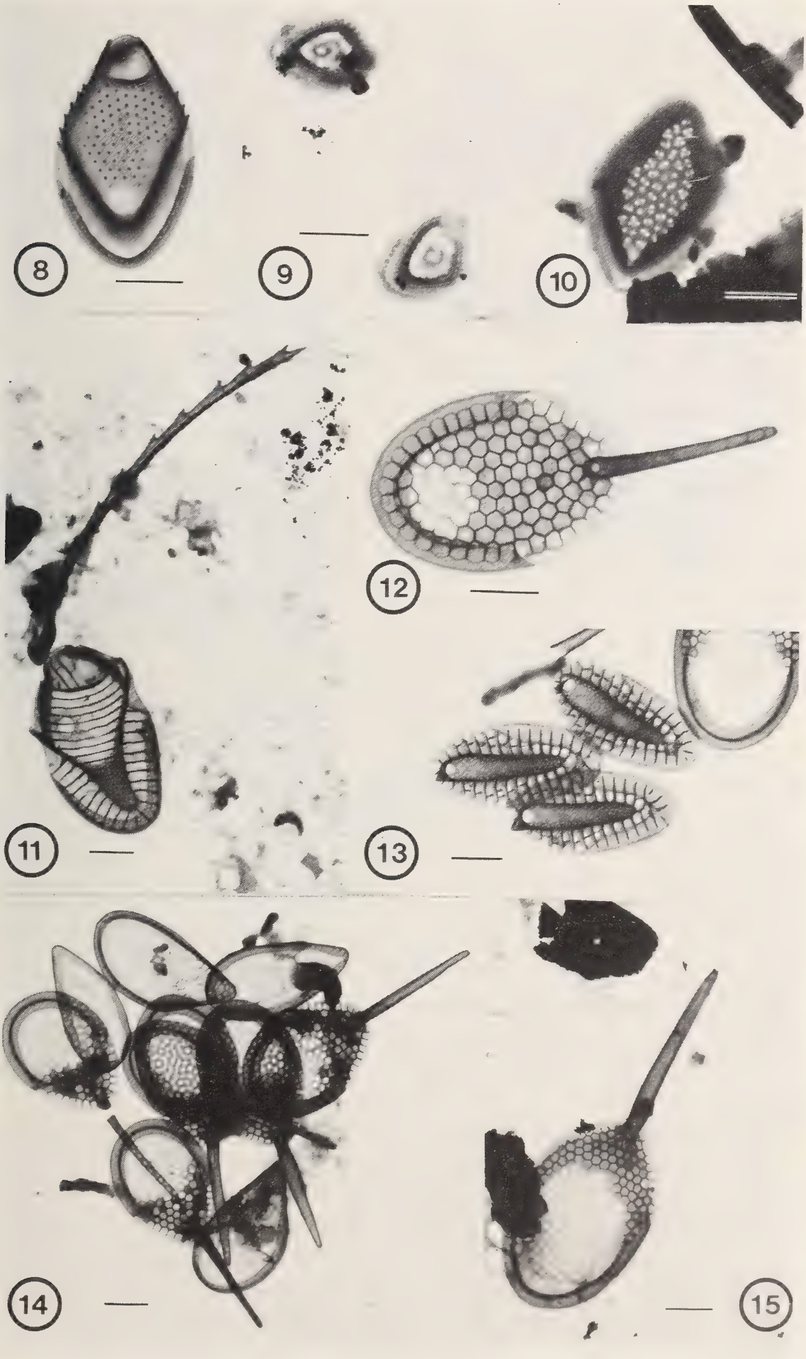
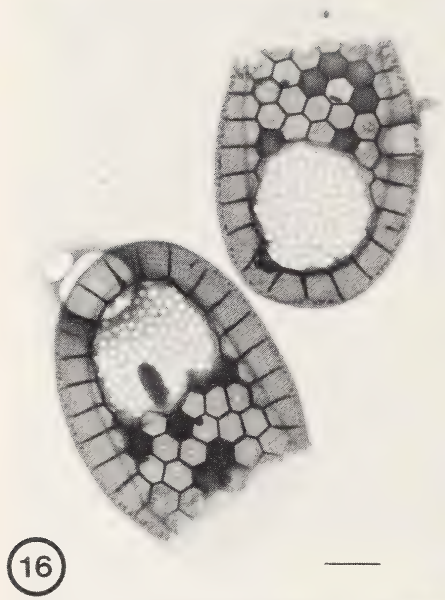
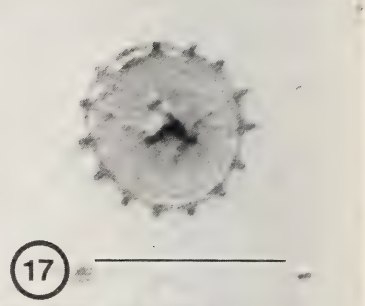
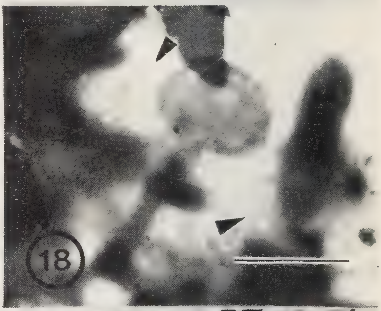
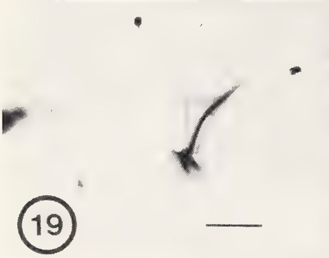


FIG. 8 *Mallomonas papillosa* var. *papillosa*. FIG. 9. *M. pillula* f. *pillula*. FIG. 10. *M. pumilo* var. *pumilo*. FIG. 11. *M. sphagniphila*. FIG. 12. *Synura mollispina*. FIG. 13. *S. petersenii* f. *kufferathi*. FIG. 14. *S. spinosa* f. *spinosa*. FIG. 15. *S. spinosa* f. *longispina*. Scale bar = 1 μm.









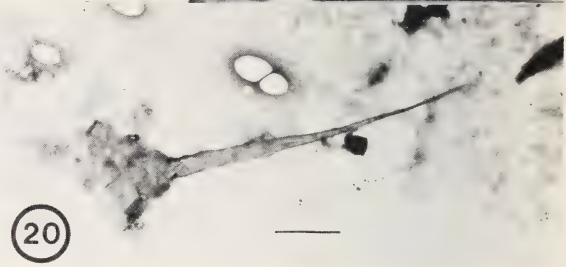


FIG. 16. *Synura uvella.* FIG. 17. *P. undulata.* FIG. 18. *Paraphysomonas stephanolepis.* FIG. 19. *Spiniferomonas alata.* FIG. 20. *S. bourrellyi.* Scale bar = 1 μm.

Paraphyasomonas stephanolepis Preisig and Hibberd (Fig. 18). This is the second report for North America. Its initial report from Arizona was as *P. butcheri* Pennick and Clark (Gretz et al., 1979) and represents a misidentification.

P. undulata Preisig and Hibberd (Fig. 17). Reported only from four other world-wide locations, our collections represent its second occurrence in North America.

**Spiniferomonas alata* Takahashi (Fig. 19). Nicholls (1989) has suggested that *S. genuiformis* Wujek & Bland may be a form variation of this taxon. The main difference separating the two taxa relates to the presence or absence of the extended median rib of the spine scale with characteristic bend and pointed angle. The spine scales of the Florida collections lacked these features.

S. bourrellyi Takahashi Fig. 20. A species usually associated with dystrophic waters.

A few corrections on a number of nomenclatural changes are needed since the publication of the previous two papers in this series (Wujek, 1984; Wujek and Gardiner, 1985) and in addition to those of Wujek (1983) and Wujek and Bland (1988). The following taxonomic annotations are grouped by genera.

In their monograph of *Mallomonas*, Asmund and Kristiansen (1986), changed the rank of *Mallomonopsis* to a subgenus. Thus, *Mallomonopsis elliptica* is now known as *Mallomonas matvienkoae* (Mat.) Asmund & Kristiansen. From Dürrschmidt's (1983) study on the *Mallomonas mangofera* group of species, the species reported as *M. mangofera* can now be referred to as var. *foveata* Dürrschmidt. Wujek's (1984) figure 32 can now be placed in the newly described species *M. guttata* Wujek.

The organism described as *Paraphysomonas septipunctata* Wujek & Gardiner has been combined within the genus *Spiniferomonas* and is synonymous with *S. septispina* Nicholls.

From a phytogeographical point of view the Florida chrysophycean flora is composed largely of species which are common in temperate waters. Only *M. bronchartiana* has been found in the tropics to date (Dürrschmidt & Cronberg, 1989) and for the first time north of the Tropic of Cancer (Cronberg, 1989).

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LITERATURE CITED

ASMUND, B. 1959. Electron microscope observations on *Mallomonas* species, and remarks on their occurrence in some Danish ponds and lakes III. Dansk Bot. Ark. 18:1-50.

———— AND J. KRISTIANSEN. 1986. The genus *Mallomonas* (Chrysophyceae). Opera Botanica 85:1-128.

COMPERE, P. 1974. *Mallomonas bronchartiana*, Chrysophycee nouvelle du lac Tchad. Bull. Jard. Bot. Nat. Belg. 44:61-63.

CRONBERG, G. 1989. Biogeographic studies. Scaled chrysophytes from the tropics. Beiheft Nova Hedwigia 95:191-232.

DÜRRSCHMIDT, M. 1983. A taxonomic study of the *Mallomonas mangofera* group (Synuraceae, Chrysophyceae) including the description of four new taxa. Plant Syst. Evol. 143:179-196.

———— AND R. CROOME. 1985. Mallomonadaceae (Chrysophyceae) from Malaysia and Australia. Nord. J. Bot. 5:285-298.

———— AND G. CRONBERG. 1989. Contribution to the knowledge of tropical chrysophytes: Mallomonadaceae and Paraphysomonadaceae from Sri Lanka. Arch. Hydrobiol. Suppl. 82:15-327.

GRETZ, M. R., M. R. SOMMERFELD, AND D. E. WUJEK. 1979. Scaled Chrysophyceae of Arizona: A preliminary survey. Ariz.-Nev. Acad. Sci. 14:17-21.

NICHOLLS, K. H. 1984. Four new *Mallomonas* species of the Torquatae series. Can. J. Bot. 62:1583-1591.

————. 1987. Form variation in *Mallomonas asmundiae* and a description of *Mallomonas sphagniphila* sp. nov. (series *Corncontícae*, Mallomonadaceae). Can. J. Bot. 65:627-634.

————. 1988. Additions to the *Mallomonas* (Chrysophyceae) flora of Ontario, Canada and a checklist of North American *Mallomonas* species. Can. J. Bot. 66:349-360.

————. 1989. *Spiniferomonas genuiformis* and *Spiniferomonas alata* (Chrysophyceae): taxonomic implications of a form variation. Can. J. Bot. 67:1294-1297.

SMOL, J. P., D. F. CHARLES, AND D. R. WHITEHEAD. 1984a. Mallomonadacean microfossils provide evidence of recent lake acidification. Nature 307:628-630.

———. 1984b. Mallomonadacean (Chrysophyceae) assembledges and their relationships with limnological characteristics in 38 Adirondack (New York) lakes. Can. J. Bot. 62:911-923.

Wawrzyniak, L. A. and R. A. Andersen. 1985. Silica-scaled Chrysophyceae from North American boreal forest regions in Northern Michigan, U.S.A. and Newfoundland, Canada. Nova Hedwigia 41:127-145.

Wee, J. L. 1982. Studies on the Synuraceae (Chrysophyceae) of Iowa. Bibl. Phycol. 62:1-183.

Wujek, D. E. 1983. A new freshwater species of *Paraphysomonas* (Chrysophyceae: Mallomonadaceae). Trans. Amer. Micros, Soc. 102:165-168.

———. 1984. Chrysophyceae (Mallomonadaceae) from Florida. Florida Scient. 47:161-170.

———. 1986. Studies on Michigan Chrysophyceae. VI. Mich. Bot. 25:93-97.

——— and R. G. Bland. 1988. *Spiniferomonas* and *Mallomonas:* description of two new taxa of Chrysophyceae. Trans. Amer. Micros. Soc. 107:301-304.

——— and W. E. Gardiner. 1985. Chrysophyceae (Mallomonadaceae) from Florida. II. New species of *Paraphysomonas* and the prymnesiophyte *Chrysochromulina.* Florida Sci. 48:59-63.

——— and M. J. Igoe. 1989. Studies on Michigan Chrysophyceae. VII. Beiheft Nova Hedwigia 95:269-280.

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Biological Sciences

Occurrence of a South American Armored Catfish in the Hillsborough River, Florida—Mark E. Ludlow[1] and Stephen J. Walsh[2]

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Abstract: *This note reports the presence of a South American catfish in the Hillsborough River, Hillsborough County, Florida. Although loricariid catfishes have been reported from the Tampa Bay area for several decades, until recently they had not been documented from the Hillsborough River drainage. The construction of a new canal system may have allowed ingress of* Pterygoplichthys *cf.* multiradiatus *into the Hillsborough River proper. A brief morphological description of three specimens is presented. Future research into the biological and ecological impacts of this algae-feeding armored catfish is strongly recommended.*

Burgess (1958) first reported the occurrence of a South American loricariid catfish in Hillsborough County, Florida. He discovered a population of what was identified as *Plecostomus* sp. living in Six-Mile Creek, an independent tributary of Tampa Bay that is located between the Hillsborough and Alafia rivers. Barnett (1972) surveyed the freshwater fishes of the Hillsborough River drainage and did not collect armored catfish, but he repeated the report by Burgess on their presence in Six-Mile Creek. Courtenay and Hensley (1979) surveyed the exotic fishes of North America and reported the existence of loricariids, identified as *Hypostomus* sp., in Nevada, Texas, and Hillsborough and Dade Counties in Florida. The Tampa Bypass Canal, constructed by the Southwest Florida Water Management District, was completed in December of 1982 (Hung Nguyen, 1989). The opening of this waterway evidently provided a corridor thorough which the loricariid population in Six-Mile Creek was able to spread into the Hillsborough drainage. Armored catfishes were first observed in Hillsborough River State Park by rangers in November 1986 (Thompson, 1989). On 12 May 1989, three voucher specimens (UF 79623) were collected and sent to the Florida Museum of Natural History, University of Florida, Gainesville. The location at which these specimens were collected is at least 10 river miles upstream from the presumed point of entrance of the population into the Hillsborough River, thus indicating rapid dispersal throughout the upper part of the river.

Accurate identification of this exotic species is difficult because of the unresolved taxonomy of hypostomine loricariids, and since the area in South America where the Hillsborough River population originally came from is unknown. We tentatively identify the above specimens as *Pterygoplichthys* cf. *multiradiatus*, a species originally described from material collected in the Demerara drainage of Guyana, and one that is commonly imported and raised by tropical fish farms in the Tampa area. The specimens measured 355,400, and 455 mm in standard length (SL). We provide the following observations on their external morphology for comparative purposes. The fin ray counts of the three specimens are: dorsal fin, I + 12 (3); pectoral fin, I + 6 (3); pelvic fin, I + 5 (3); principal (branched) caudal rays, 12 (1), 14 (2). All three specimens have four rows of lateral dermal scutes between the dorsal and pectoral fins; an additional row of scutes is present above the anal fin, beginning over the pelvic fin base and extending to the base of the tail. Scute counts for the three sublateral rows are as follows: midlateral row, 30 (3);

TABLE 1.—Summary of proportional measurements of *Pterygoplichthys* cf. *multiradiatus* (UF 79623; N = 3) from the Hillsborough River, Florida. Measurements 2-18 are expressed as thousandths of standard length (SL, in mm); measurements 19-21 are expressed as thousandths of head length (HL, in mm).

	Range	Mean
1. Standard Length (mm)	355-445	—
2. Preadipose fin length	774-797	786
3. Preanal fin length	530-591	553
4. Predorsal fin length	329-334	332
5. Prepelvic fin length	348-396	367
6. Prepectoral fin length	190-210	200
7. Pectoral fin origin to pelvic origin	165-212	184
8. Pectoral fin origin to dorsal origin	202-234	221
9. Pelvic fin origin to dorsal origin	214-228	221
10. Adipose fin origin to anal insertion	124-138	131
11. Dorsal fin insertion to adipose origin	81-107	94
12. Body width at pectoral fin origin	191-213	205
13. Body width at pelvic fin origin	135-152	142
14. Dorsal spine length	196-238	212
15. Pectoral spine length	249-281	264
16. Caudal peduncle length	242-258	251
17. Least caudal peduncle depth	68-77	74
18. Snout to dorsal point of gill opening (HL)	200-215	205
19. Least bony interorbital width	523-578	549
20. Anterior internarial width	216-252	232
21. Horizontal eye diameter	116-123	119

sublateral row, 29 (1), 30 (2); infrasublateral rows, 23, 24, and 25. In all three specimens there are four dermal plates between the orbits, and five middorsal scutes between the dorsal fin insertion and adipose fin origin. The specimens exhibit a characteristic reticulated color pattern that is typical of that described for *P. multiradiatus*. Morphometrics of the specimens are summarized in Table 1.

Casual observations indicated that *Pterygoplichthys* is presently abundant in Hillsborough River State Park. Their worm-like feces are conspicuous in shallow areas of the river bottom. Loricariids feed on algae, other plant material, and detritus (Courtenay et al., 1974). Eutrophication of the Hillsborough River, which has resulted in heavy algal growth on benthic substrates, has probably been beneficial to this species. The potential impact of this exotic catfish on the community ecology of the Hillsborough River is unknown and merits further study. Moreover, a systematic survey of the Hillsborough River is needed to determine if there is more than one species of loricariid presently inhabiting the river, as well as to determine if and to what extent this and other exotic fishes have become established in the drainage.

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LITERATURE CITED

BARNETT, B. S. 1972. The freshwater fishes of the Hillsborough River drainage, Florida. M.S. Thesis, Univ. South Florida, Tampa.

BURGESS, E. J. 1958. The fishes of Six-Mile Creek, Hillsborough County, Florida, with particular reference to the presence of exotic species. Proc. Ann. Meet. S.E. Assoc. Game and Fish Comm., Louisville, Ky., 12:1-8 (pagination from reprint).

COURTENAY, W. R., H. F. SAHLMAN, W. W. MILEY, II AND D. J. HERREMA. 1974. Exotic fishes in fresh and brackish waters of Florida. Biol. Conserv., 6(4):292-302.

_________, AND D. A. HENSLEY. 1979. Introduced exotic fishes in North America: status 1979. Unpublished report to the National Fishery Research Laboratory, U.S. Fish and Wildlife Service, University of Florida, Gainesville, Florida.

NGUYEN, H. 1989. South West Florida Water Management District, Brooksville. Personal Communication.

THOMPSON, K. 1989. Weedon Island State Preserve, St. Petersburg, Florida. Personal Communication.

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NEUROCHEMICAL EVENTS ASSOCIATED WITH LEARNING AND HUNTING BEHAVIOR IN THE SPIDER WASP, *PEPSIS FORMOSA* (HYMENOPTERA, POMPILIDAE)

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ABSTRACT: *A significant increase in neural RNA and protein synthesis was associated with avoidance learning and hunting behavior in the spider wasp,* Pepsis formosa. *Cycloheximide-induced inhibition of protein synthesis significantly impaired learning. The cerebral ganglion was associated with avoidance learning and hunting as indicated by the degree of incorporation of* H^3*-labeled uridine into RNA in specific protocerebral regions including the corpora pedunculata and protocerebral bridge as compared to those found in nontrained controls. Specific behavioral components of the hunting sequence exhibited behavioral plasticity. Cellular and molecular mechanisms of learning and memory and their relationship to brain function in arthropods are discussed.*

RESEARCH studies conducted over the last decade on the cellular and molecular mechanisms associated with learning (behavioral plasticity) have led to several generalizations: (1) learning involves changes in neural circuits that are correlated with alterations in synaptic efficacy; (2) training procedures result in changes in membrane currents; (3) learning involves second messenger systems; and (4) behavioral plasticity is associated with changes in macromolecular synthesis within the central nervous system (CNS) (see reviews by Punzo, 1985a; Bear et al., 1987; Byrne, 1987). Proposed cellular mechanisms for learning include reverberating circuits, modification of dendritic processes and synapses, and use-dependent modification of neural pathways (Farley and Alkon, 1985). Although these ideas have been applied to both the vertebrate and invertebrate CNS, invertebrate models are particularly well suited for this type of analysis owing to their relative simplicity in contrast with vertebrate systems. Invertebrates that have been used in studies on the cellular and neurochemical basis of learning and memory include gastropod molluscs (Kandel and Schwartz, 1982; Bailey and Chen, 1983; Alkon, 1984; Shuster et al., 1985), decapod crustaceans (Punzo, 1983), coleopteran, orthopteran and dipteran insects (Jaffe, 1980; Maldonado, 1980; Punzo, 1980; Punzo and Jellies, 1980; Quinn, 1984; Punzo and Malatesta, 1988), and theraphosid spiders (Punzo, 1988a, b). Specific neurochemical changes that accompany learning include increases in brain RNA and protein synthesis and a decrease in cholinesterase activity (Punzo, 1985a; Black et al., 1987). These neurochemical events have also been used to identify specific anatomical loci within the brain that are believed to be involved in the mediation of the learning process. Significant increases in RNA and protein synthesis accompanying avoidance learning were found in the basal forebrain of *Anolis sagrei* (Punzo, 1985b), the protocerebral bridge and central body of the mud crab, *Eurypanopeus depressus* (Punzo, 1983), the corpora pedunculata and central body of the tarantula spider, *Aphonopelma chalcodes* (Punzo, 1988a), and the corpora pedunculata and protocerebral bridge of the grasshopper, *Schsitocerca americana* (Punzo, 1980). Inhibition of protein synthesis within the CNS was found to impair learning in vertebrates (Flexner et al., 1967; Mayor, 1979; Punzo, 1985b) as well as orthopteran and coleopteran insects (Jaffe, 1980; Punzo, 1980) and theraphosid spiders (Punzo, 1988a). It was also found to impair the innate phototactic behavior of tenebrionid beetles (Punzo and Jellies, 1980) suggesting that even rigid (closed) behavioral programs are dependent upon ongoing neurochemical events.

Presently, there is little information on neurochemical correlates of learning and memory and localization of brain function for many insect groups including the Hymenoptera. The purpose of the present study was to investigate neurochemical events (changes in brain RNA and protein synthesis) associated with behavioral plasticity in the spider wasp, *Pepsis formosa,* for which no information is currently available. Since previous studies on insects have almost exclusively confined themselves to analyses of habituation, sensitization, classical or operant conditioning (see Alloway, 1973; Punzo, 1985a), the present study utilized the following behaviorial paradigms: (1) leg-position, shock avoidance learning, and (2) the effects of experience on hunting behavior. Adult female *Pepsis* wasps selectively hunt large tarantula spiders in deserts of the southwestern United States and Mexico (Punzo and Garman, 1989) as well as tropical regions in Central and South America. The female wasp locates a tarantula host, paralyzes it and then deposits a single egg on its abdomen (for a detailed description of this hunting behavior the reader is referred to Petrunkevitch, 1926, and Cazier and Mortenson, 1964). The emergent wasp larva then feeds upon the host. Any improvement in the overall performance of the hunting sequence as a function of the number of encounters with a suitable host would be evidence of a modification of behavior based on past experience (learning). There is no information currently available concerning neurochemical events associated with this type of naturally-occurring, complex behavior. In addition, changes in brain RNA and protein synthesis associated with the learning paradigms listed above were used to identify specific brain regions that might be involved in the control of these behaviors.

METHODS—Eggs and pupae of *P. formosa* were collected from burrows of parasitized tarantula spiders *(Dugesiella echina)* in sotol-grassland habitats in Brewster Co., Texas, and transported back to the laboratory. Newly emergent adult wasps were collected by sweep net while on the ground or perched on creosote bushes *(Larrea tridentata)* or mesquite *(Prosopis glandulosa).* Adult wasps were sexed, placed separately in one-liter glass containers and fed on a diet of honey and sugar water. All adult female wasps used in these experiments had no previous encounter experience with the host spider. Additional non-parasitized tarantulas were collected from the same area and maintained in the laboratory as previously described by Punzo (1988a, b).

Shock avoidance, leg-position learning—The protocol used for all learning experiments has been previously described in detail (Goldsmith et al., 1978; Punzo, 1980, 1988a). To summarize, each female wasp was anaesthetized with CO_2 prior to training and some melted paraffin wax was placed on the dorsal surface of the prothorax. A small metal rod (1 mm. diam.) was inserted into the soft wax so that the insect could be suspended directly above a saline solution. A copper wire lead was attached to the tarsus of the right metathoracic leg with a surgical clip and the leg was then allowed to hang freely. The remaining legs were tethered in a raised position with surgical thread. The metathoracic leg and copper wire lead were suspended over a glass bowl containing a 0.9% NaCl solution. Failure to flex the leg resulted in contact with the salt solution and the completion of an electrical circuit which delivered a shock (square wave pulses) of 20V amplitude and 30 msec duration at a frequency of 6 Hz. Wasps were allowed to recover from anaesthetization for one hr prior to training procedures. Previous studies had shown that this was sufficient time for the wasp to resume normal activity (Punzo and Garman, 1989; Punzo, 1990). The criterion for learning was the change in the number of shocks received over a 10 min training period. A Simpson Model 87R automatic counter was used to record the number of shocks received. H^3-labeled isotonic physiological saline was injected into the cervical region of each experimental animal as described by Punzo (1983). During learning experiments, 10 female wasps were assigned randomly to an experimental (P) or yoke-control (R) group. Each experiment consisted of paired P and R wasps positioned adjacent to each other. The P animal received a shock whenever the metathoracic leg made contact with the saline solution. The R wasp received a shock whenever the P animal was shocked regardless of its leg position. The total number of shocks was recorded for each P-R pair over the 10-min training period. Following this, the wasps were left unstimulated for one hr and then retested (retest P) for another 10-min period in order to determine the degree of retention (memory) of the leg flexion task.

Behavioral modification of hunting behavior—Experiments were also conducted to determine if the hunting behavior of these wasps can be modified based on previous experience. Encounters were staged between an individual wasp and spider in an encounter chamber. This chamber (40 × 35 × 40 cm) has been previously described by Punzo and Garman (1989), and was constructed of clear plexiglass and provided with a sand substrate. A burrow was constructed at one end of the chamber (5 cm diam.). A female tarantula was placed in the burrow 24 hr prior to an encounter. Each encounter sequence was initiated by introducing a female wasp into the chamber. The time required for the completion of the various behavioral components (acts) of the overall hunting sequence was recorded from the time the wasp entered the chamber. The following behavioral components were analyzed: (1) AP (initial approach and antennation)—approach of the wasp to the burrow and its ability to force the spider out of its retreat. The wasp then explores the body of the spider with its antennae (antennation); (2) MG (moving away and grooming)—the wasp retreats a short distance and cleans the antennae with its mouthparts; (3) AnP (antennation and paralyzation)—the wasp again antennates the body of the host and then paralyzes the spider by inserting its stinger through the ventral articulation membranes of the cephalothorax and into the ventral nerve cord; (4) BO (burial and oviposition)—the paralyzed spider is dragged into the burrow and a single egg deposited on its abdomen; (5) C (closure of the burrow). Complete encounter sequences were recorded for 17 *P. formosa* females. A decrease in the amount of time required to complete the overall hunting sequence would indicate an improvement in performance based on previous experience. These wasps, as well as those used in the shock avoidance experiments described above, were then subjected to neurochemical analyses.

Neurochemical correlates of behavioral plasticity—Studies were conducted to determine the relationship between neural RNA and protein synthesis and avoidance learning using procedures previously described by Kerkut and co-workers (1972) and Punzo (1988a). Briefly, another P group of 10 wasps was subjected to the avoidance learning protocol described above. Following training, each wasp was injected into the head region with cycloheximide (CXM, Sigma) as reported by Punzo and Jellies (1980). CXM has been shown to inhibit protein synthesis within the central nervous system (CNS) (Barraco and Stettner, 1976; Jaffe, 1980; Punzo, 1988a). Following CXM injection, wasps were isolated for one hr and then retested (PC). Another group (C) of 10 wasps was treated with CXM one hr prior to the training period. Two sham control groups of 10 wasps were injected with physiological saline before (S) and after (SP) the training procedure.

Additional experiments were conducted to determine the magnitude of changes in brain RNA and protein synthesis associated with avoidance learning and hunting (encounter) experience. Following training procedures, wasps were anaesthetized and the brains (cerebral ganglia) removed from experimental (P), yoke-control (R) and nontrained control animals using the surgical procedure reported by D'Alessio and co-workers (1982). Brains were also removed from wasps that had experienced at least eight encounters with a host spider and compared with those removed from wasps that had no previous encounter experience. Brains were homogenized in a Frey Model HC110 homogenizer. A 10% trichloracetic acid (TCA) solution was added to the homogenate to precipitate RNA and protein (Kerkut et al., 1972). The precipitate was washed with cold 5% TCA and then extracted in hot 5% TCA. Following centrifugation, an aliquot of this supernatant was used for the determination of RNA concentration using the orcinol method described by Oliver (1973). Another aliquot was dissolved in butyl:methanol:toluene scintillant and analyzed in a Beckman LS scintillation counter. RNA concentrations were expressed as the degree of incorporation of H^3-labeled uridine into RNA (counts/min/ug RNA) as described by Punzo (1983). To determine the protein concentration, the remaining precipitate was washed with 1.0N NaOH and then extracted with hot 1.0N NaOH. An aliquot was dissolved in scinitillation fluid and protein content determined by the method of Lowry and co-workers (1951) and expressed as the degree of incorporation (counts/min/ug protein) of H^3-labeled leucine (Tocris Neuramin) into protein.

Localization of brain function—Levels of RNA synthesis were used to identify specific brain regions associated with avoidance learning as reported by Punzo (1980, 1985a). Another group of 10 wasps received shock avoidance training. Following this, the brains were removed and the degree of incorporation of H^3-labeled uridine into RNA was determined for the following brain regions: protocerebrum (P), deutocerebrum (D), tritocerebrum (T), corpora pedunculata (CP), protocerebral bridge (pb) and central body (cb). Specific brain regions were identified according to the procedures and nomenclature of Vowles (1955) and Bullock and Horridge (1965).

RESULTS—The data in Table 1 indicate that *P. formosa* is capable of leg-position, shock avoidance learning. The P animals received a significantly higher number of shocks ($\overline{X}=57.3$) during the first minute of training as compared to the number received ($\overline{X}=3.1$) at the end of the 10 min training period. An ANOVA (Steele and Torrie, 1960) showed the overall improvement in performance to be highly significant ($F=41.23$, df = 1/9, $p<0.01$). No improvement in performance was exhibited by the yoke-control (R) wasps. An ANOVA showed a significant difference between the performance of the P and R groups ($F=29.44$, df = 1/9, $p<0.01$). In addition, these wasps also showed the ability to retain the learned response (Table 1, retest P) following a 60 min interest interval. Retest P animals averaged significantly fewer shocks during the first min of the initial training period. A direct-difference Student t-test (Steele and Torrie, 1960) showed this improvement to be significant ($t=5.12$, df = 9, $p<0.01$). These shock avoidance procedures resulted in a change in behavior that persisted for 48 hr. Also, even though

TABLE 1. Shock avoidance, leg-position learning in the wasp, *Pepsis formosa*. Values represent mean number of shocks over a 10 min training period for experimental learning (P), experimental retest (retest P) and yoke-control (R) groups. Numbers in parentheses indicate ±1.0 S.E.M. (N = 10/group).

Training Time (Min)	Groups Tested		
	P	Retest P	R
1	57.3 (6.1)	14.6 (2.3)	61.2 (7.8)
2	51.7 (4.7)	9.7 (2.1)	57.4 (6.1)
3	34.1 (5.2)	11.4 (1.7)	49.6 (6.3)
4	23.6 (3.1)	10.3 (1.1)	51.8 (4.6)
5	19.2 (2.3)	7.5 (0.8)	54.1 (4.9)
6	16.4 (1.8)	4.1 (0.4)	47.5 (4.1)
7	10.3 (1.4)	5.2 (0.3)	70.2 (7.4)
8	6.1 (0.6)	3.7 (0.2)	51.5 (6.5)
9	6.4 (0.7)	3.5 (0.3)	43.4 (4.4)
10	3.1 (0.2)	2.4 (0.1)	55.9 (6.1)

the R group received the same number of shocks, their performance did not improve, indicating that the change in behavior exhibited by the P wasps can be attributed to learning rather than to sensitization or general level of motor activity.

TABLE 2. The effect of encounter experience on the time required for *Pepsis formosa* females to complete the various behavioral components of the hunting sequence. Values represent the mean time (min) required to complete each behavioral component (N = 17). AP–approach and antennation; MG–moving away and grooming; AnP–antennation and paralyzation; BO–burial and oviposition; C–closure of the burrow.

			Behavioral Components			
Encounter	AP	MG	AnP	BO	C	Total
1	37.6	14.3	54.5	29.6	115.7	251.7
2	30.5	11.7	42.7	34.1	124.5	243.5
3	17.4	13.4	20.4	21.5	104.8	177.5
4	11.1	10.9	13.6	24.7	110.5	170.8
5	7.8	13.1	11.2	21.3	97.4	150.6
6	8.2	12.4	7.4	25.2	116.2	169.4
7	9.0	13.2	7.8	30.6	110.6	170.9
8	7.7	12.6	6.1	24.4	108.8	159.6

The effect of encounter experience on the time required to perform the overall hunting sequence (Table 2) was also significant ($F = 37.86$, $df = 7/122$, $p < 0.01$). The time required decreased from an average of 251.7 min for the first encounter with a tarantula host to 159.6 min after eight encounters ($t = 8.04$, $df = 9$, $p < 0.01$). In addition, only certain behavioral components were modifiable based on previous experience (Table 2, AP and AnP) whereas others (MG, BO and C) were not.

The effects of CXM-induced inhibition of brain protein synthesis on learning are shown in Table 3. CXM treatment following the initial period of training (Table 3, PC) resulted in a significant impairment in performance as compared to that exhibited before drug treatment (P) ($t = 4.16$, $df = 9$, $p < 0.01$). Insects that received CXM prior to training (C group) showed no

TABLE 3. Effects of cycloheximide (CXM) on shock avoidance learning in the wasp, *Pepsis formosa.* Values represent mean number of shocks over a 10 min training period for experimental learning (P) animals, sham-controls treated with insect saline before (S) and after (SP) training, and animals treated with CXM before (C) and after (PC) training. (N = 10/group).

Training Time (min)	Groups Tested				
	P	C	PC	S	SP
1	60.4	81.5	65.5	62.4	60.1
2	52.2	78.4	54.7	51.7	54.5
3	33.7	71.2	51.3	37.1	30.9
4	24.5	84.6	47.2	26.5	24.3
5	18.6	64.5	38.9	17.1	19.6
6	15.1	59.3	37.6	13.4	16.1
7	9.5	70.4	42.1	8.4	9.3
8	5.2	57.6	29.3	5.8	5.4
9	4.9	64.1	39.6	5.1	4.4
10	3.3	70.4	27.8	4.1	3.6

indication of avoidance learning even though they appeared quite normal in other respects (alertness, general motor activity, feeding, righting response). An ANOVA showed that the overall effect of CXM on learning was significant ($F = 19.43$, $df = 1/9$, $p < 0.01$). No significant differences were found between the P group and sham controls injected with saline before (S) or after (SP) training.

TABLE 4. Effects of shock avoidance learning on the incorporation of H^3-labeled uridine into RNA and leucine into protein in the brain of *Pepsis formosa*. RNA and protein values are expressed as means ± 1.0 S.E.M. (N = 10/group). Levels of significance computed using a Student t-test.

Test Group	Counts/min ug Protein	Counts/min/ ug RNA	P
Nontrained Controls	84.6 ± 4	254.6 ± 9	NS
Yoke Controls	96.1 ± 7	271.2 ± 6	0.01
Experimental	143.5 ± 8	423.5 ± 8	

The effects of training procedures on the incorporation of H^3-labeled uridine into RNA and leucine into protein in the brain of *P. formosa* are shown in Table 4. In both cases, significantly higher levels of incorporation were associated with the brains of experimental animals as compared to nontrained controls. Yoke-control wasps showed an intermediate level of incorporation that did not differ significantly from nontrained controls and may be attributable to a general increase in motor activity. These results indicate that avoidance learning is associated with significant changes in macromolecular synthesis within the CNS of this wasp.

The effects of encounter experience (hunting behavior) on the incorporation of H^3-labeled uridine into RNA and leucine into protein are shown in Table 5. Those wasps which experienced at least eight successful and complete encounters with a host spider exhibited significantly higher activity counts associated with brain RNA and protein synthesis than control wasps having no encounter experience but exposed to identical rearing conditions. This difference reflects actual neurochemical changes within the CNS attributable to the learning process and not merely to a general increase in motor activity since control wasps were allowed to fly, feed and explore a host-free

TABLE 5. Effects of encounter experience on the incorporation of H^3-labeled uridine into RNA and H^3-leucine into protein in the brain of *Pepsis formosa*. Values represent means ± 1.0 S.E.M. (N = 10). Encounter group represents those wasps that had 8 encounters with a tarantula host; controls represent wasps with no encounter experience. Level of significance computed using a Student t-test (Steele and Torrie, 1960).

Test Group	Counts/min/ ug RNA	Counts/min/ ug Protein
Encounter	373.4 ± 11	130.4 ± 10
Controls	260.6 ± 8	79.1 ± 6
p	0.01	0.01

encounter chamber on a daily basis. They were also of comparable size (within ±0.1 g) and the same age as the wasps used in encounter trials. The only consistent difference between these two groups was the encounter experience with host spiders. This represents the first demonstration of changes in brain RNA and protein synthesis associated with a naturally-occurring behavior consisting of sequential acts.

The degree of incorporation of H^3-labeled uridine into RNA in various brain regions as a function of learning is shown in Table 6. Significant increases in RNA synthesis were found in the entire protocerebrum (P), CP and pb. No significant changes were associated with the cb, D or T regions. These results indicate that specific protocerebral regions such as the CP and pb play an important role in the mediation of the learning process in *P. formosa*.

TABLE 6. Effects of shock avoidance learning on the incorporation of H^3-labeled uridine into RNA in various brain regions of *Pepsis formosa*. RNA values represent means for 10 wasps. Brain regions according to Bullock and Horridge (1965): P (entire protocerebrum), CP (corpora pedunculata), pb (protocerebral bridge), cb (central body), D (deutocerebrum), T (tritocerebrum). Level of significance computed using a Student t-test; NS = not significant.

	Mean RNA activity (counts/min/ug RNA)		
Specific CNS Regions	Experimental	Nonstrained Controls	p
P	176.4	69.8	0.01
CP	94.6	31.5	0.01
pb	45.2	11.7	0.01
cb	39.7	37.4	NS
D	12.5	14.1	NS
T	14.1	13.6	NS

DISCUSSION—The results of the present study show that intact *P. formosa* wasps are capable of exhibiting avoidance learning (Table 1). Although various types of learning (habituation, operant conditioning, olfactory imprinting) have been demonstrated for insects (see reviews by Alloway, 1973 and Punzo, 1985a), few studies have made attempts to correlate behavioral changes with neurochemical events or with specific regions within the CNS associated with the learning process. The results also indicate that the observed changes in behavior are associated with a significant increase in brain RNA and protein synthesis (Table 4). In addition, the increase in RNA synthesis is associated with specific anatomical regions of the protocerebrum including the CP and pb (Table 6). This is in agreement with what little information is available on localization of brain function and behavioral plasticity in insects and other arthropods (see review by Punzo, 1985a). Increases in brain RNA synthesis associated with avoidance learning procedures were found in the pb and cb of the decapod crustacean, *E. depressus* (Punzo, 1983), the CP and cb of the tarantula spider, *A. chalcodes* (Punzo, 1988a), and the CP and pb of the grasshopper, *S. americana* (Punzo, 1980). This firmly establishes the association between the protocerebrum and learning in arthropods. However, since headless insect preparations are also capable of exhibiting some degree of leg-position learning (see review by Byrne, 1987) apparently mediated by the ventral nerve cord (VNC), the functional relationship between the VNC and higher brain centers in the acquisition and retention of learned tasks still remains to be determined. The importance of the protocerebrum in the mediation of other forms of learning in arthropods has been demonstrated. For example, destruction of the alpha lobes of the CP resulted in an impairment of olfactory conditioning in the wood ant, *Formica rufa* (Vowles, 1964). Also, the alpha lobes have been implicated in short-term memory processes in the honeybee (Menzel et al., 1974). More recently, it has been shown that the number of fibers within the CP of *Drosophila melanogaster* is significantly reduced in flies reared in social isolation (Technau, 1984), and CP mutants are deficient in olfactory learning (Heisenberg et al., 1985).

The results show that behavioral modifications associated with hunting behavior (Table 5) are also accompanied by significant changes in neurochemistry. This is in agreement with the biochemical model of learning which suggests that experiential information entering the CNS is accompanied by macromolecular events involved in the alteration/formation of synaptic connections and modification of synaptic events including postsynaptic membrane thresholds (Farley and Alkon, 1985; Black et al., 1987). Previous experimental results support this view. Memory consolidation was accompanied by changes in brain peptides in cockroaches (Kerkut et al., 1972) and mantids (Maldonado, 1980), and subsequent studies indicated that this consolidation was associated with specific increases in arginine and lysine activity (D'Alessio et al., 1982). In addition, low molecular weight peptides were isolated from the brains of mantids exposed to operant training procedures (Jaffe and Maldonado, 1979) but not from nontrained controls.

The importance of RNA and protein synthesis to the learning process is also reflected in the decline in performance associated with CXM treatment. The results shown in Table 3 clearly indicate that wasps treated with CXM before (C group) and after (PC) leg-position training exhibited a significantly reduced ability to learn. This is in agreement with results reported for insects including cockroaches (Brown and Noble, 1967), mantids (Jaffe, 1980) and grasshoppers (Punzo, 1980), decapod crustaceans (Punzo, 1983), and vertebrates (Punzo, 1985b). A study by Hambley and Rogers (1979) showed that CXM-induced inhibition of protein synthesis in the brain resulted in retarded learning capacities in neonatal chicks. They also reported that the experimental alteration of amino acid pools within the brain produced CXM-like retardation in learning processes. Proteins and other low molecular weight peptides are synthesized from these pools of free (FAA) amino acids (Bear et al., 1987; Black et al., 1987; Punzo, 1987, 1988b) and so it is not surprising that changes in AA precursors might result in a disruption of synaptic processes involved in learning and memory. Enzymes involved in neurotransmitter (NT) synthesis would also be expected to impact upon the learning process. Synaptic events have long been implicated in theories of learning and memory (Hebb, 1949; Kandel and Schwartz, 1982; Alkon, 1984; Bear et al., 1987;

Byrne, 1987), and NTs as well as their receptors represent crucial factors in mechanisms involving acquisition, consolidation and retention. Indeed, behavioral modifications leading to molecular changes constitute one possible mechanism by which experimental information is translated into neural language (Bailey and Chen, 1983; Farley and Alkon, 1985). Thus, learning results in increased nerve impulse activity leading to a subsequent increase in neural RNA synthesis. This, in turn, is involved in the encoding of NTs resulting in the eventual alteration of synaptic events (Black et al., 1987). The observation that CXM-treatment is also capable of disrupting innate behavioral acts (Punzo and Jellies, 1980) suggests that protein synthesis is associated with closed behavioral programs as well.

It should be pointed out that only certain behavioral acts (AP and AnP) of the overall hunting sequence improved with experience (Table 2). It is quite plausible that certain biomechanical constraints associated with digging, oviposition and nest closure make similar improvement in BO and C improbable. Also, the importance of the accurate identification of the host spider using primarily olfactory cues as well as the location of intersegmental membranes for the successful insertion of the stinger (Cazier and Mortenson, 1964), necessitates the thorough grooming and cleaning of antennal chemorecpetors (MG) and is not likely to reflect any significant degree of plasticity. No such restrictions apply to the AP and AnP components. The significant decrease in the amount of time (i.e., handling time) required to complete these acts as a function of increasing encounter experience would reduce the amount of energy expended in the search and pursuit of each host spider. This represents an optimization of foraging behavior which could increase the number of hosts located within a given period of time as well as increase the amount of energy available for other activities such as oogenesis, territoriality, mating and predator avoidance thereby increasing overall fitness.

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LITERATURE CITED

ALKON, D. L. 1984. Calcium-mediated reduction of ionic currents: a biophysical memory trace. Science 226:1037-1045.

ALLOWAY, T. M. 1973. Learning in insects. Pp. 73-121. *In:* CORNING, W. C., DYAL, J. AND A. O. D. WILLOWS (eds.), Invertebrate Learning, Vol. 2. Plenum Press, New York.

BAILEY, C. H. AND M. CHEN. 1983. Morphological basis of long-term habituation and sensitization in *Aplysia*. Science 220:91-93.

BARRACO, R. AND L. J. STETTNER. 1976. Antibiotics and memory. Psychol. Bull. 83:343-352.

BEAR, M. F., L. COOPER, AND F. F. EBNER. 1987. A physiological basis for a theory of synapse modification. Science 237:42-48.

BLACK, I. B., J. E. ADLER, C. DREYFUS, W. F. FRIEDMAN, E. F. LAGAMMA, AND A. H. ROACH. 1987. Biochemistry of information storage in the nervous system. Science 236:1263-1268.

BROWN, B. M. AND E. NOBLE. 1967. Cycloheximide and learning in the isolated cockroach neuron, *Periplaneta america*. Brain Res. 6:363-366.

BULLOCK, T. H. AND G. A. HORRIDGE. 1965. Structure and Function in the Nervous Systems of Invertebrates, pp. 1165-1272, W. H. Freeman, San Franciso.

BYRNE, J. H. 1987. Cellular analysis of associative learning. Physiol. Rev. 67:329-439.

CAZIER, M. A. AND M. MORTENSON. 1964. Bionomical observations on tarantula hawks and their prey (Hymenoptera:Pompilidae): *Pepsis.* Ann. Ent. Soc. Amer. 57:533-541.

D'ALESSIO, G., A. DONATO, K. JAFFE, H. MALDONADO, AND N. ZABALA. 1982. Arginine and memory consolidation in the praying mantis. J. Comp. Physiol. 147:231-235.

FARLEY, J. AND D. L. ALKON. 1985. Cellular mechanisms of learning, memory and information storage. Ann. Rev. Psychol. 36:419-494.

FLEXNER, L.B., J. FLEXNER, AND R. ROBERTS. 1967. Memory in mice analyzed with antibiotics. Science 155:1377-1383.

GOLDSMITH, C. M., H. M. HEPBURN, AND D. MITCHELL. 1978. The retention of an associative task after metamorphosis in *Locusta migratoria* J. Insect Physiol. 24:737-741.

HAMBLEY, J. W. AND L. J. ROGERS. 1979. Retarded learning induced by intracerebral administration of amino acids in the neonatal chick. Neuroscience 4:677-684.

HEBB, D. O. 1949. The Organization of Behavior. Wiley and Sons, New York.

HEISENBERG, M., A. BORST, S. WAGNER, AND D. BYERS. 1985. *Drosophila* mushroom body mutants are deficient in olfactory learning. J. Neurogenetics 2:1-30.

JAFFE, K. 1980. Effects of cycloheximide on protein synthesis and memory in praying mantids. Physiol. Behav. 25:367-371.

_________ AND H. MALDONADO. 1979. A chemical correlate of learning in a praying mantis. J. Insect Physiol. 25:319-325.

KANDEL, E. R. AND J. H. SCHWARTZ. 1982. Molecular biology of learning: modulation of transmitter release. Science 218:433-443.

KERKUT, G. A., P. C. EMSEN, AND P. W. BEESLEY. 1972. Effect of leg-raising learning on protein synthesis and cholinesterase activity in the cockroach. Comp. Biochem. Physiol. 41B:635-645.

LOWRY, D. H., N. ROSEBOROUGH, A. L. FARR, AND R. RANDALL. 1951. Protein measurement with the Folin-Phenol reagent. J. Biol. Chem. 193:265-275.

MALDONADO, H. 1980. Changes in brain peptides and memory consolidation in praying mantids. J. Insect Physiol. 26:1101-1110.

MAYOR, S. J. 1979. Memory in Japanese quail: effects of puromycin and cycloheximide. Science 166:1165-1167.

MENZEL, R., J. ERBER, AND T. MASHUR. 1974. Pp. 45-76. Learning and memory in the honeybee. *In:* BARTON-BROWNE, L. (ed.), Experimental Analysis of Behavior, Springer-Verlag, New York.

OLIVER, G. W. O. 1973. Neurochemical aspects of shock avoidance learning in cockroaches. Pp. 101-129, *In:* ANSELL, G. AND P. BRADLEY (eds.), Macromolecules and Behavior, Park Press, Maryland.

PETRUNKEVITCH, A. 1926. Tarantula versus tarantula hawk: a study in instinct. J. Exp. Zool. 45:367-397.

PUNZO, F. 1980. Neurochemical changes associated with learning in *Schistocerca americana* (Orthoptera:Acrididae). J. Kansas Entomol. Soc. 53:787-796.

_________. 1983. Localization of brain function and neurochemical correlates of learning in the mud crab, *Eurypanopeus depressus* (Decapoda). Comp. Biochem. Physiol. 75A:299-305.

_________. 1985a. Recent advances in behavioral plasticity in insects and decapod crustaceans. Fla. Entomol. (Insect Behavioral Ecology Symposium) 68:89-104.

_________. 1985b. Neurochemical correlates of learning and role of the basal forebrain in the brown anole, *Anolis sagrei* (Lacertilia, Iguanidae). Copeia 1985(2):409-414.

_________. 1987. Physiological amino acids in brain tissue of the lepismatids, *Lepisma saccharina* and *Thermobia domestica* (Insecta, Thysanura). Comp. Biochem. Physiol. 88C:255-258.

_________. 1988a. Learning and localization of brain function in the tarantula spider, *Aphonopelma chalcodes* (Orthognatha, Theraphosidae). Comp. Biochem. Physiol. 89A:465-470.

_________. 1988b. Physiological amino acids in the central nervous system of the tarantulas, *Aphonopelma chalcodes* and *Dugesiella echina* (Orthognatha, Theraphosidae). Comp. Physiol. 90:107-113.

_________. 1990. The hemolymph composition and neurochemistry of the spider wasp, *Pepsis formosa* (Say) (Hymenoptera:Pompilidae). Comp. Biochem. Physiol. (in press).

_________ AND B. GARMAN. 1989. Effects of encounter experience on the hunting behavior of the spider wasp, *Pepsis formosa* (Say) (Hymenoptera:Pompilidae). Southwest. Nat. 34(4):513-518.

_________ AND J. JELLIES. 1980. Effects of cycloheximide induced protein synthesis inhibition on the phototactic behavior of Tenebrio molitor (Coleoptera: Tenebrionidae) and Popilius disjunctus (Coleoptera: Passalidae). J. Kansas Entomol. Soc. 53:597-606.

_________ AND R. MALATESTA. 1988. Brain RNA synthesis and the retention of Learning through metamorphosis in *Tenebrio obscurus* (Insecta, Coleoptera). Comp. Biochem. Physiol. 91A:675-679.

QUINN, W. G. 1984. Work on invertebrates on the mechanisms underlying learning. Pp. 197-246. *In:* MARLER, P. AND H. S. TERRACE (eds.), The Biology of Learning, Springer-Verlag, New York.

SHUSTER, M. J., J. COMARDO, S. A. SIEGELBAUM, AND E. R. KANDEL. 1985. Cyclic-AMP dependent protein kinase close serotonin-sensitive channels of *Aplysia* sensory neurons in cell-free membrane patches. Nature 313:392-393.

STEELE, R. G. AND J. H. TORRIE. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York.

TECHNAU, G. M. 1984. Fiber number in the mushroom bodies of adult *Drosophila melanogaster* depends on age, sex and experience. J. Neurogenetics 1:113-126.

VOWLES, D. M. 1955. The structure and connections of the corpora pedunculata in bees and ants. Quart. J. Microsc. Soc. 96:239-255.

_________. 1964. Olfactory learning and brain lesions in the wood ant, *Formica rufa.* J. Comp. Physiol. Psychol. 58:105-111.

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REVIEW

Wendy B. Zomlefer. *Flowering Plants of Florida: A Guide to Common Families.* Biological Illustrations, Inc., Gainesville, FL. 1989. Pp. xi + 207. Price: $25.00, paperback.

This book is a revised and slightly expanded edition of *Common Florida Angiosperm Families, Part 1* (1983) and *Part* 2 (1986). It consists of descriptive text and illustrations of 73 vascular plant families which are arranged according to the Thorne system of classification. The individual family treatments are concise and well written. The illustrations are of excellent quality and highly informative. One very nice feature is the addition of illustrations to the glossary. This is particularly helpful to beginning students, for whom this book is intended. Although the author states that the number of families is increased from 70 in the original editions to 73, this is somewhat misleading as the major difference is simply a realignment of families. The Moraceae is now included in the Urticaceae, and the Melanthiaceae, Agavaceae, Amaryllidaceae, and Alliaceae are separated from the Liliaceae. Further consequences brought by the Thorne system are that the Asclepiadaceae are included with the Apocynaceae, the Apiaceae with the Araliaceae, and the Orobanchaceae with the Scrophulariaceae. The Cronquist system, increasingly used in the U.S., recognizes these six families as distinct. Although somewhat of a minor inconvenience to those of us who do not use the lesser known Thorne system in our teaching, it does draw attention to the affinities of these families and is useful for that reason. I have used *Common Florida Angiosperm Families* in my courses and will certainly adopt *Flowering Plants of Florida* in the future. It is an excellent source book with well executed illustrations and accurate text. I highly recommend it for use, not only in taxonomy and field botany courses, but as a reference for anyone interested in Florida plants. Although written specifically for Florida, its usefulness extends throughout the lower southeast.—Richard P. Wunderlin, Department of Biology, University of South Florida, Tampa, FL 33620.

ACKNOWLEDGMENT OF REVIEWERS

It is a pleasure to acknowledge the service, dedication, and cooperation of the following persons who gave generously of their time and expertise in reviewing manuscripts for volume 53 of the *Florida Scientist.* Some reviewers reviewed more than one manuscript.

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Florida Academy of Sciences
Fifty-Fourth Annual Meeting—Melbourne, March 1990

AGRICULTURAL SCIENCE

Graham, J. Wright, Dept. of Ornamental Horticulture, University of Florida, "Container Shape Influences Growth of Weeping Fig". Graduate Co-Award

Peter A. Krottje, Agronomy Dept., University of Florida, "Effect of Explant Source on Callus Growth and Shoot Regeneration in Desmodium". Graduate Co-Award

ANTHROPOLOGICAL SCIENCE

Nina T. Borremans, Dept. of Anthropology, University of Florida, "Prehistoric Human Settlement and Paleogeography in the Cedar Keys Region, Florida". Graduate Award

Nancy Schoenberg, Dept. of Anthropology, University of Florida, "Food Classification and Consumption Patterns among Rural Black Female Diabetics in Alachua County". Honorable Mention

Ashley Swift, Dept. of Anthropology, University of Florida, "Pedological Investigations of Shell Midden Site Formation in the Cedar Keys Wildlife Refuge". Honorable Mention

BIOLOGICAL SCIENCES

Gary A. Cecchine III, Division of Science, University of Tampa, "Lectins Block Mate Recognition in the Rotifer *Brachionus plicatilis*". Undergraduate Award

Donald J. McGarey, Dept. of Biology, University of South Florida, "Detection of Virulence-Associated Factors Produced by Bacteria Isolated from Fish Exhibiting Ulcerative Disease Syndrome (UDS)". Graduate Award

COMPUTER SCIENCE AND MATHEMATICS

P. A. Kairis, Dept. of Applied Mathematics, Florida Institute of Technology, "Parallelization of the Monte Carlo Method". Undergraduate Award

Nalina Suresh, Dept. of Mathematics, University of South Florida, "Weibull Model for the Prediction of Software Reliability Using Bayes Empirical Bayes Approach". Graduate Award

ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCES

John T. Butcher, Millar Wilson Laboratory for Chemical Research, Jacksonville University, "Elemental Carbon as a Component of Urban Atmospheric Total Suspended Particulate Matter". Undergraduate Award

Elsie Gross, Institute for Environmental Studies, Department of Chemistry, University of South Florida, "The Role of Iron in the Growth of *Lyngbyax majuscula*. Graduate Award.

SCIENCE TEACHING

Kevin Barry, Science Education Department, Florida Institute of Technology, "The Design and Validation of the Barry Environmental Aptitude Test (BEAT)". Graduate Award

SPECIAL AWARDS

CENTRAL FLORIDA CHAPTER, THE EXPLORERS CLUB AWARD

Nina T. Borremans (see Anthropological Science Graduate Award winner)

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AWARD

UNDERGRADUATE AWARDEES:

Melissa Massaro, Dept. of Anthropology, University of Florida, "A Modern Fishing Method in Cedar Key".

Gary A. Cecchine III (see Biological Science Undergraduate Award winner)

HIGH SCHOOL AWARDEES (FLORIDA JUNIOR ACADEMY OF SCIENCES):

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Donald J. McGarey (see Biological Sciences Graduate Award winner)

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Srinivasan Iyengar, Dept. of Physics and Space Sciences, Florida Institute of Technology, "Electron-Ion Interactions and Electromigration".

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FLORIDA SCIENTIST

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Biological Sciences

ROAD MORTALITIES OF NORTHERN FLORIDA VERTEBRATES

CRIS CRISTOFFER

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ABSTRACT: *Results from a survey of road mortality of vertebrates in Northern Florida indicated that mortality correlated positively with speed limit and density of vegetative cover, but the influence of traffic volume was apparently masked by the influence of speed limit.*

THE primary purpose of this study was to assess the relative importance of several influences on road mortality. Mortality of vertebrates on roadways has been correlated to several factors. There seems to be a consensus that mortality is positively related to speed limit (Case, 1978; Dickerson, 1939; Haugen, 1944; Knudsen, 1973; McClure, 1951; Scott, 1938; Stoner, 1925). However, there is confusion in the literature as to the influence of traffic volume and roadside vegetation. Allen and McCullough (1976) noted a positive correlation between traffic volume and road mortality in deer, but Case (1978) found no significant association. The lack of agreement on the importance of traffic volume could be due to any number of factors, but one seems particularly relevant. The few general road-kill surveys in the southeastern U.S. have not repeatedly quantified speed limit, traffic volume and cover, yet if these variables influence each other, then studies to assess the importance of one variable should simultaneously assess the influence of the others. This was attempted in the present study.

MATERIALS AND METHODS—To obtain data on road mortality, I drove standard routes in Alachua County from June to September 1989. The routes began on Archer Rd. at the University of Florida in Gainesville, Florida. The 'Alachua' route included Archer Rd. (a portion of State Rd. 24), SW 122nd St., W. Newberry Rd., County Rd. 241, State Rd. 235, County Rd. 241, County Rd. 236, and State Rd. 121. This route was 30.5 km long. On several occasions I went only as far along this route as a site on County Rd. 241, then returned; the one-way distance along this portion was 4.1 km.

The 'Waldo' route was Archer Rd., State Rd. 141, State Rd. 24, Interstate Highway 301, State Rd. 26, Interstate Highway 301, State Rd. 20, State Rd. 141, and Archer Rd. This route was 39.3 km long.

Both routes were travelled twice weekly, typically from 09:30 hrs to about 14:00 hrs, with frequent stops. All data were recorded in these time intervals, and portions of routes that were traveled twice in several hours (to go to and from a site to gather information for an unrelated study) were assessed only once per day. This irregularity in methodology was, however, of little consequence, since there were never fresh kills on the return trip.

At the site of each mortality I recorded the location, taxonomic identity of road-kills (species for mammals and the alligator, higher taxa for the other vertebrates), local speed limit and a general appraisal of vegetative cover. Vegetative cover was also recorded every 0.5 km along the routes. The subjective ranking used a score of one to three, with one representing very little cover and three, heavy cover that could provide substantial concealment from terrestrial predators or prey. Pastures, lawns, and unvegetated areas were classified as '1'. Vegetation that appeared to limit vision at about one m above the ground to only a few meters, as well as forests in which trees were not aligned in rows, were ranked '3'. Intermediate conditions, ranked '2', included tree plantations in which trees grew widely-spaced and in rows, as well as roads on one side of which vegetation was ranked '1' and the other, '3'. Time constraints precluded more objective methods of appraisal; however, I used the same criteria for kill sites as for overall assessments. Although detailed characterizations were not possible, it seemed clear that urban areas rarely had high plant cover, but that rural areas varied from low cover (e.g., pastures) to high cover (e.g., most forests). Roads with extensive rural habitat included State Rd. 20, County Rd. 241, and County Rd. 301. Approximately 5,000 km of road were assessed during the entire study.

On divided highways, only the road surface on the right side of the median was monitored. Posted speed limits ranged from 48.3 to 88.5 km per hour, and traffic was assumed to travel faster in the higher speed limit zones. The percentages of road length in the various speed limit zones were 1.92 for 48.3 km/hr; 6.73 for 56.3 km/hr; 7.58 for 64.4 km/hr; 16.91 for 72.4 km/hr; 0.65 for 80.3 km/hr; and 66.22 for 88.5 km/hr. These fractions were used to calculate expected frequencies for null hypotheses. For example, 66.22% of road mortalities were expected to occur in 88.5 km/hr speed zones. Traffic volume was recorded in each speed limit zone as the number of vehicles (cars, trucks and motorcycles) per second in 15-minute sampling intervals.

Seven mortalities (six *Dasypus* and one *Didelphis*) along 0.5 km of road in Waldo, Florida, were not included in these analyses. There were strong indications that factors other than roadside cover and traffic volume were implicated in these mortalities. Furthermore, there was also a question of which speed limit category to assign these mortalities to. Although the posted speed was 48.3 km/hr, the specimens were very close to a higher speed limit zone; traffic here frequently exceeded the posted speed limit (pers. obs.).

Parametric multivariate techniques were unsuitable for assessing relations among variables I recorded in Alachua County because underlying distribution assumptions were not met, hence nonparametric methods (Agresti and Agresti, 1979) were used. Kendall's tau-b was considered the most appropriate for comparisons among many variables. Chi-square goodness-of-fit analyses were used to assess independence in road-kill distributions by habitat type. Road-kills concentrated along a particular portion of roadway in the city of Waldo were excluded (see above), as were domestic species.

RESULTS AND DISCUSSION—The road mortalities of the vertebrate taxa, per km of roadway (Table 1) are lower than those reported for most areas of the U.S., but are most comparable to those from Dickerson (1939) for the eastern U.S., including northern Florida. Studies such as those of Case (1978) are not comparable because the information therein is expressed in a per time rather than a per km basis. Several taxa were recorded both in the current study and in Dickerson (1939), and for these, relative abundances should be compared. For clarity, such calculations should exclude taxa rare or absent in either survey. Using this criteria, the percentages for the relevant taxa the older study and the current study are, respectively, 4.2 and 36.6 for *Didelphis;* 48.6 and 17.1 for *Sylvilagus;* 1.4 and 26.8 for *Sciurus;* 22.2 and 6.1 for passerines; and 23.6 and 13.4 for herptiles. The change in percentages through time are consistent with the notion that the relative abundances of scavengers and omnivores has increased through time, perhaps because increasing road density provides more road-killed food for such species. Although there is no way to test this directly, a general comparison of relative abundances of taxa with varying trophic habits (e.g., scavengers, herbivores, predators) from areas of low and high density of roads, would be most enlightening.

TABLE 1. Taxa and frequencies of road mortalities along several routes in Alachua County, Florida, June-September 1989.

Taxa	Frequency	Frequency/100 km
Didelphis virginiana Virginia opossum (Marsupialia: Didelphidae)	30	0.61
Dasypus novemcinctus Nine-banded armadillo (Edentata: Dasypodidae)	58	1.18
Sylvilagus floridanus Eastern cottontail (Lagomorpha: Leporidae)	14	0.28
Sciurus carolinensis Gray squirrel (Rodentia: Sciuridae)	22	0.45
Procyon lotor Raccoon (Carnivora: Procyonidae)	13	0.26
Felis rufus Bobcat (Carnivora: Felidae)	1	0.02
Odocoileus virginiana White-tailed deer (Artiodactyla: Cervidae)	1	0.02
Wild duck (Anseriformes: Anatidae)	1	0.02
Vulture (Falconiformes: Cathartidae)	1	0.02
Hawk (Falconiformes: Accipitridae)	3	0.06
Owl (Strigiformes: Strigidae)	2	0.04
Passerine bird (Passeriformes)	5	0.10
Turtle and tortoise (Chelonia)	4	0.08
Snake (Squamata: Serpentes)	6	0.12
Toad (Anura)	1	0.02

Positive correlations were found between mortalities and speed limit (tau-b=0.67, $P<0.01$) and mortalities and vegetative cover (tau-b=0.16, $P=0.03$). This somewhat counterintuitive association could actually be spurious, as follows. Traffic volume was significantly negatively correlated with speed limit (tau-b= −0.37, $P=0.023$). It seems quite possible that the lower mortality in high volume locations could be due to the low speed limit at such locations. If speed limit is the more important factor, the tendency for mortality to increase with speed should overwhelm the opposing tendency for mortality to increase where volume is greatest (that is, at low speeds). Data are insufficient to test this assertion rigorously, but it gains some support from the literature: there is a consensus that speed is an important influence on road mortality, but the influence of traffic volume is questionable until speed is controlled. Vegetative cover was, however, clearly related to mortality. The percent occurrences of road kills at low, medium and high cover, were 30, 39 and 37, respectively; these were significant using a Chi-square goodness-of-fit test ($0.05 < P < 0.01$) from the values of 35, 31 and 34% for the same categories taken at 159, 0.5-km intervals.

Several factors were probably important in determining road mortality. Speed limit and high vegetative cover tended to increase mortality rates, whereas the influence of traffic volume could not be assessed with much confidence because there is a strong possibility that volume effects are masked by speed limit effects. Although I was unable to statistically control for speed limit because time constraints precluded observations of traffic volume at each kill site, such attempts are recommended for future study.

LITERATURE CITED

Agresti, A. and B. F. Agresti. 1979. Statistical Methods for the Social Sciences. Dellen, San Francisco. 554 pp.

Allen, R. E. and D. R. McCullough. 1976. Deer-car accidents in southern Michigan. J. Wildl. Manage. 40(2):317-325.

Case, R. M. 1978. Interstate highway road-killed animals: a data source for biologists. Wildl. Soc. Bull. 6:(1)8-13.

Dickerson, L. M. 1939. The problem of wildlife destruction by automobile traffic. J. Wildl. Manage. 3(2):104-116.

Haugen, A. O. 1944. Highway mortality of wildlife in southern Michigan. J. Mammal. 25(2):177-184.

Knudsen, G. J. 1973. The fast four-wheeled predator. Wisconsin Conserv. Bull. 38(1):22-23.

McClure, H. L. 1951. An analysis of animal victims on Nebraska's highways. J. Wildl. Mange. 15(4):410-420.

Scott, T. G. 1938. Wildlife mortality on Iowa highways. Am. Midl. Nat. 20(3):527-539.

Stoner, D. 1925. The toll of the automobile. Science 61(1568):56-57.

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WATER RELATIONS OF SCRUB OAKS ON THE LAKE WALES RIDGE, FLORIDA

ERIC S. MENGES AND NOREEN P. GALLO

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ABSTRACT: *We studied seasonal water relations in three scrub oak species on the southern Lake Wales Ridge during 1989. Xylem water potential and soil-water content were used to characterize site and species differences in moisture status. Plants in scrubby flatwoods had the lowest water potential, especially during times of more severe drought. On sandhill sites, moisture status was most favorable. Site differences in predawn xylem potential were not correlated with site differences in distance to water table or site differences in surface (0-40 cm) soil moisture.* Quercus chapmanii *had more negative water potentials than the other oaks studied. These results suggest site and species difference in water relations and the potential for different drought adaptations among the oak species.*

UPLAND—ecosystems on the southern Lake Wales Ridge are characterized by plants with xeromorphic adaptations. Such characters as curled, thick, hairy, waxy leaves define xeric communities such as sand pine scrub and scrubby flatwoods (Abrahamson et al., 1984). These two ecosystems are dominated by woody shrubs and small trees with large root systems, which recover rapidly from periodic fire by resprouting (Abrahamson, 1984a). The presence of xeromorphic features may be due to either low water or nutrient availability in scrub and related communities.

The ridges that support scrub and other Lake Wales Ridge upland communities are composed of excessively well-drained pure sand soils (Myers, 1990). These soils have extremely low water-holding capacity (Carter and Lewis, 1982) and may promote stressful conditions during the winter drought season. Such soils are also notably low in many nutrients important to plant growth, particularly phosphorus (Abrahamson et al., 1984; Myers and White, 1987; Anderson, 1990). Thus, plant species growing on the sandy soil have to contend with both drought and nutrient stress. Nutrient uptake and availability generally decrease during drought (Abrams, 1988a).

No studies of drought or nutrient stress on Lake Wales Ridge habitats have been published, although plant distribution has been related to distance from the water table (Abrahamson et al., 1984). Southern ridge sandhill, sand pine scrub, scrubby flatwoods, and flatwoods exist as a series of communities with decreasing distance from the water table. It is generally assumed that water and nutrient availability are largely responsible for this gradient (Kurz, 1942; Abrahamson et al., 1984; Huck, 1987). Adaptations to water stress along gradients of water availability have been found in other landscapes both between (Abrams, 1988b; Anderson et al., 1988) and within species (Roy and Lumaret, 1987).

The question of whether species and community distributions reflect water availability requires direct measures of water relations. In 1987 and 1988 woody plant predawn water potentials remained high (near zero) through nearly a year and a half of periodic measurements at Archbold Biological Station (Denton, 1989).

Of the many water relations parameters that describe parts of the atmosphere-plant-soil continuum, xylem water potential may be the most robust (Kramer and Kozlowski, 1979). Water potential gradients provide the driving force for water movement and stomatal closure often occurs at threshold plant water potentials (Hinckley et al., 1978). Plant water potentials are least variable before dawn, when rehydrated plants achieve equilibrium with soil water potentials at their effective rooting depth (the soil depth at which a plant extracts the bulk of its moisture). Thus, predawn plant water potentials describe overall soil moisture conditions at which the plant begins each day (Hinckley et al., 1978; Romo and Haferkamp, 1989). Predawn water potentials are also important indicators of other physiological parameters. Predawn water potentials below a threshold value may be associated with lower peak leaf conductances (Hinckley et al., 1978) and earlier stomatal closure on the following day. Thus, predawn potentials are useful measures of moisture status through a drought season. They do not, however, provide a complete analysis of plant adaptations to drought or of stress experienced by plants during drought.

We hypothesized that predawn plant water potentials in scrub and related communities would differ from zero in a normal or drier than normal drought season. In 1989, the current study was initiated to test this hypothesis. We also hypothesized site and species differences in predawn water potential. This paper provides the first tests of site and species differences in water relations for Florida scrub.

METHODS—Research was carried out at Archbold Biological Station in southern Highlands County, on the southern part of the Lakes Wales Ridge (Fig. 1). Four sites were selected, each differing in distance from the water table and in some soil characters (Table 1). All sites have been unburned for at least 20 years and are located adjacent to wells that monitor ground water level. The four sites are southern ridge sandhill, sand pine scrub (rosemary phase), scrubby flatwoods and flatwoods. The vegetation of these sites (summarized in Table 1) has been described in detail (Laessle, 1958; Abrahamson et al., 1984; Myers, 1985).

The three oak species studied were *Quercus myrtifolia* (not present in rosemary scrub site), *Quercus chapmanii* (present at all sites), and *Quercus inopina* (not present in sandhill site). Based on their distributions at Archbold Biological Station, *Q. myrtifolia* and *Q. chapmanii* would be ranked as more xeric species than *Q. inopina.* All oaks are evergreen with new leaves being flushed in the spring as old leaves fall. All three species recover from fire by resprouting (Abrahamson, 1984b; Johnson et al., 1986).

Plant water potential data were collected before dawn seven times from the four sites between January 12 and June 8, 1989, and weekly at the scrubby flatwoods site. This period of time constitutes the last five months of the seven month drought season for south-central Florida. A portable pressure chamber was used to make all measurements (Scholander et al., 1965). Twigs were placed in the pressure bomb immediately after cutting. At each site six individuals of each species were used for water potential measurements. These individuals were flagged and the same individuals were followed throughout the drought season. The water potential sampling removed a minuscule proportion of the leaf area of individual trees and thus should not affect plant water relations. All water potential measurements were made before sunrise. Additional readings made in early morning show that readings at this time of the morning were stable.

Soil moisture content was determined gravimetrically (as % of dry weight) during many

TABLE 1. Vegetation and soil information for water relations sites at Archbold Biological Station.

Site	Distance From Water Table*	Soil	Soil Drainage Class	Available Water Capacity	Clay Pct.**	Dominant Species
Sandhill	24.5-25.2m	Astatula	Excessively well-drained sand.	.02-.05	1-3	*Pinus elliottii* var. *densii* *Quercus chapmanii* *Q. myrtifolia* *Q. geminata* *Q. laevis* *Aristida stricta*
Rosemary scrub	2.6-3.0m	St. Lucie	Excessively well-drained sand.	.02-.05	<2	*Ceratiola ericoides* *Q. inopina* *Q. chapmanii*
Scrubby flatwoods	2.2-2.6m	Duette	Moderately well-drained sand.	.03-.06	<2	*Q. inopina* *Q. chapmanii* *Q. geminata* *Lyonia fruticosa*
Flatwoods	1.2-1.8m	Immokolee	Poorly-drained fine sand.	.05-.10	1-5	*P. elliottii* var. *densa* *Serrenoa repens* *Q. chapmanii* *Q. myrtifolia* *Lyonia lucida*

*During study period: January-June 1989.

**From Carter and Lewis (1982); values are general for soil series and not necessarily from study sites. Values from surface soils.

sample periods. Five samples per site were collected from each of two horizons, 0-20 cm, and 20-40 cm.

At biweekly intervals, well-water heights at each of the four sites were determined. In addition, information on rainfall and fog were collected daily at a weather station at Archbold Biological Station.

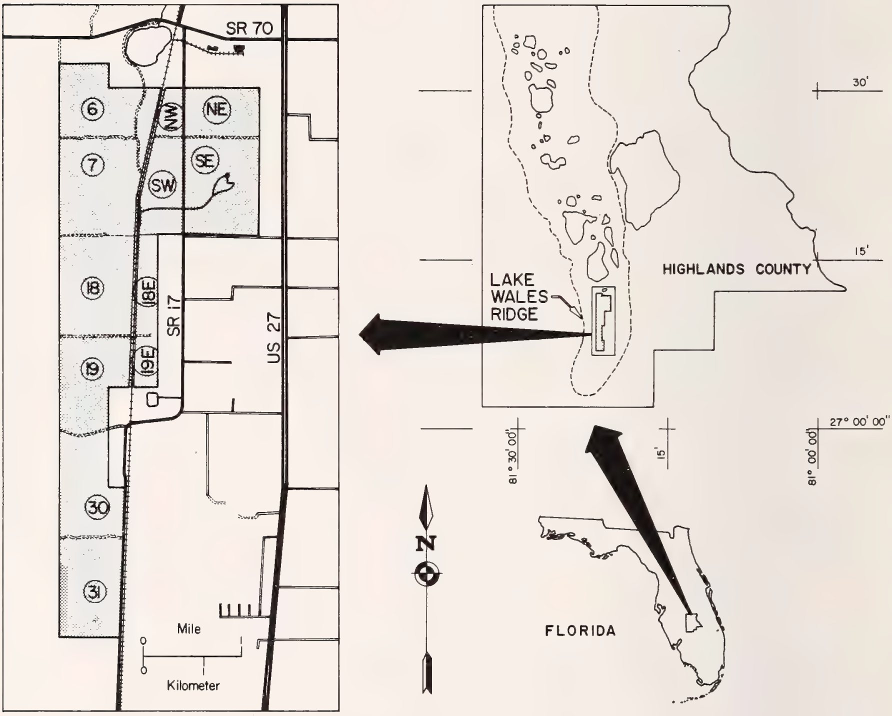

FIG. 1. Location of Archbold Biological Station, south-central Florida. Rosemary scrub is in Section 6, Sandhill in Section SE, and other sites in Section SW.

RESULTS—The 1988-1989 drought season at Archbold Biological Station was slightly drier than mean conditions over the last two decades (Table 2). About 48 cm of rain fell between October 1988 and May 1989 with important drought periods in early 1989. Predawn plant water potential responded to periodic rainfall. At each site, water potentials became lowest in early Febru-

TABLE 2. Rainfall (cm) at Archbold Biological Station, 1972-1988, by season.

	1986-87	1987-88	1988-89	Mean 1972-1988
June-September	93.5	53.9	63.3	75.2
October-May	54.1	74.0	48.3	52.8

ary, when average readings of −0.5 to −0.7 MegaPascals (MPa) were recorded (Fig. 2). A second drought period occurred in early April. By mid-June, with the onset of the summer rainy season, predawn water potentials climbed > −0.25 MPa, where they stayed for the remainder of the summer.

Differences among species and sites were evident on many of the sampling dates. For example, on Feb. 2, 1989 (Fig. 3), when drought was most severe, predawn water potentials varied significantly across both species and sites (two-way analysis of variance, $P<0.0001$ for both variables). On this date *Q.*

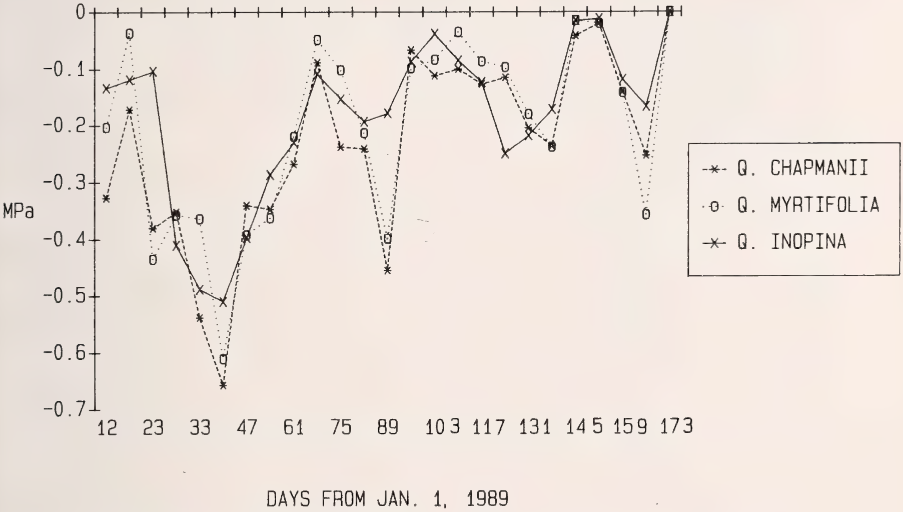

FIG. 2. Predawn plant water potentials for oak species in scrubby flatwoods, 1989.

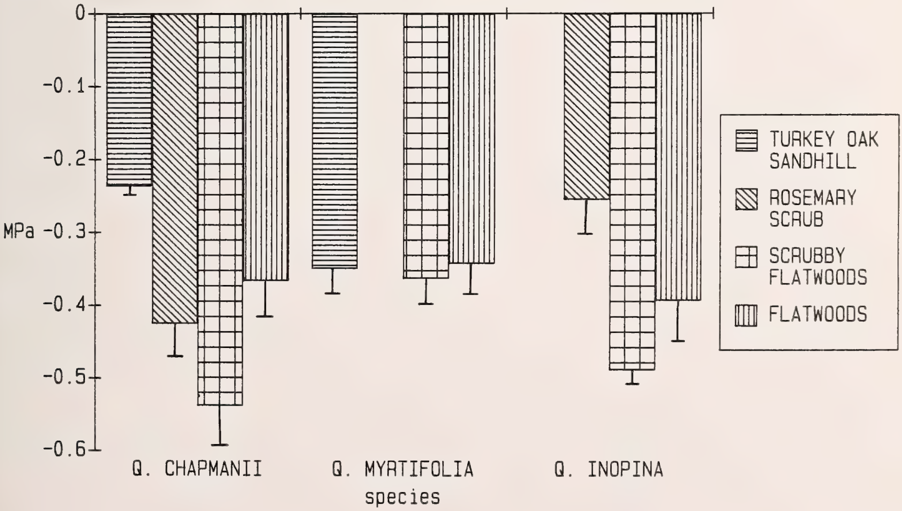

FIG. 3. Predawn plant water potentials by species and site, Feb. 2, 1989. Error bars are 1 standard error.

chapmanii exhibited the lowest water potentials (Tukey's Least Significant Difference Test). Among sites, plants at scrubby flatwoods exhibited the lowest water potentials (Fig. 3).

On April 20, 1989 (Fig. 4), when drought stress was very mild, species and site patterns were similar. Again, both site and species were significant in two-way analysis of variance ($P<0.001$). Again, *Q. chapmanii* had the lowest potentials, and scrubby flatwoods was the site with lowest plant water potentials (Fig. 4).

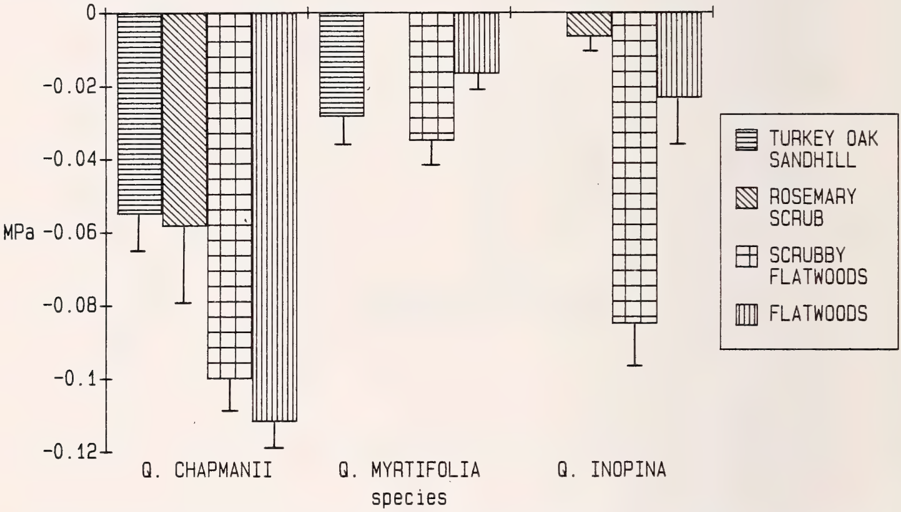

FIG. 4. Predawn plant water potentials by species and site, April 20, 1989. Error bars are 1 standard error.

Among the seven dates when all sites were sampled, significant differences were noted on four (Table 3, left side). *Q. chapmanii* had the lowest potentials on three of the dates with *Q. myrtifolia* lowest on January 23, 1989. Similarly, at scrubby flatwoods, *Q. chapmanii* most often had the lowest predawn water potentials when species differed (Table 3, right side). In a few cases where overall water potentials were close to zero, *Q. inopina* was the lowest. However, in these cases significance levels were usually not as great as during times of lower water potential.

Site differences in predawn water potential were significant on six of seven sample dates. Four of six times scrubby flatwoods was detected as having the lowest potentials of any site using Tukey's Least Significant Difference Criteria (Table 4). Sandhill sites had among the highest water potential readings on all sample dates where significant site differences were found. Rosemary scrubs were the lowest on two dates (Table 4).

Soil moisture content also varied among sites on three sample dates. In each case sandhill sites had the lowest soil moisture content and flatwood sites had the greatest soil moisture content (Fig. 5). Differences were significant for 0-20 cm soil on all three sample dates and 20-40 cm soil on 2 of 3 sample dates. On 2 of 3 sample dates when soil was collected, plants had water

TABLE 3. Species differences in predawn water potential in scrubby flatwoods (right) and over all four sites (left), 1989.

Date	Mean Potential (MPa)	Significance of Species	Species With Lowest Water Potentials	Mean Potential (MPa)	Significance of Species	Species With Lowest Water Potentials
12 Jan	−0.16	NS	—	−0.21	NS	—
19 Jan				−0.11	NS	—
23 Jan	−0.40	*	Q.m.	−0.31	***	Q.m.
26 Jan				−0.37	NS	—
2 Feb	−0.38	***	Q.c.	−0.46	*	Q.c.
9 Feb				−0.59	*	Q.c.
16 Feb				−0.38	NS	—
23 Feb	−0.26	NS	—	−0.33	NS	—
2 March				−0.24	NS	—
9 March				−0.08	*	Q.i.
16 March				−0.16	***	Q.c.
23 March	−0.24	**	Q.c.	−0.22	NS	—
30 March				−0.34	***	Q.c.
6 April				−0.08	NS	—
13 April				−0.08	*	Q.c.
20 April	−0.06	***	Q.c.	−0.07	***	Q.c.
27 April				−0.11	NS	—
4 May				−0.15	***	Q.i.
11 May				−0.20	NS	—
18 May				−0.22	NS	—
25 May	−0.04	NS	—	−0.02	*	Q.i.
1 June				−0.02	NS	—
8 June				−0.13	NS	—

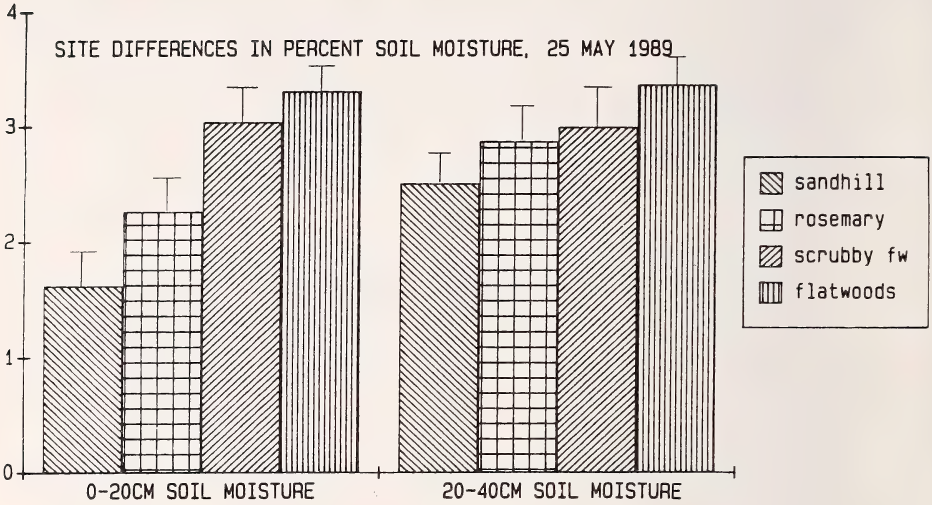

FIG. 5. Percent soil moisture, by soil depth and site, May 25, 1989. Error bars represent 1 standard error among 5 samples.

potentials near zero, and on the third date plants had moderately negative water potentials but there were no site differences in predawn water potential. Site means for soil water content were never significantly correlated with any mean species predawn plant water potential (over all sites, r = 0.12, 0.23, 0.42 for the three species, for individual sites, r ranged from 0.08 to 0.57 for species/site combinations).

DISCUSSION—The three oak species exhibited substantial negative predawn water potentials during the peak drought periods of 1989 indicating oak species on scrub and related sites on the Lake Wales Ridge may be drought-stressed. Data on conductance and growth are now being collected to test the effects of water potential on plant performance. The minimum site

TABLE 4. Site differences in predawn water potential, three oak species, 1989.

Date	Mean Potential	Significance of Site	Lowest Potentials†	Highest Potentials†
12 Jan	−0.16	*	Scrubby Flatwoods	Sandhill, Flatwoods
23 Jan	−0.40	***	Rosemary Scrub	Scrubby Flatwoods, Sandhill
2 Feb	−0.38	**	Scrubby Flatwoods	Sandhill
23 Feb	−0.26	*	Scrubby Flatwoods	Sandhill
23 Mar	−0.24	NS	—	—
20 Apr	−0.06	**	Scrubby Flatwoods	Rosemary, Sandhill
25 May	−0.04	***	Rosemary Scrub	Scrubby Flatwoods, Sandhill

* $P<0.05$
** $P<0.01$
*** $P<0.001$
NS not significant
† As determined by Tukey's Least Significant Difference Criteria.

and species means of −0.5 to −1.0 MegaPascals (MPa) suggest the possibility of moderate drought stress during a drought season (1988-1989) that had slightly less rainfall than average.

The finding of negative predawn water potentials contrast with findings of the previous 1-1/2 years at Archbold Biological Station (Denton, 1990). During that study, no predawn readings lower than −0.1 MPa were found, suggesting no water stress for the oaks and other species measured. However, during that drought season, rainfall was at least 20 cm above average (Table 2). We suspect the predawn water potentials may become quite a bit lower during years with severe drought.

Site differences in predawn water potentials were not related to depth to water table or surface (0-40 cm) soil moisture. We found the trees at scrubby flatwoods had generally lower potentials than trees in other ecosystems, especially sandhills. The site order of increasing plant water potential from scrubby flatwoods through rosemary scrub, flatwoods, and sandhill does not correspond to decreasing site order in depth to water table. At our sites, sandhill trees are rooted over 20 m from the water table. Rosemary scrub, scrubby flatwoods, and flatwoods trees are within 5 m of the water table in order of decreasing distance from the water table. This order in depth to water table also corresponds to the site order in soil moisture content. That is, sandhill soils contain less water than rosemary scrub, scrubby flatwoods, and flatwoods, which are most mesic. These findings contrast to a previous study finding similar soil moisture contents in sandhill, rosemary scrub, and scrubby flatwoods (Abrahamson et al., 1984). However, mean predawn water potentials were not related to mean surface (0-40 cm) soil moisture contents for any species.

The fact that site differences in water table depth and surface soil moisture content do not correspond with site differences in plant water potential is a mystery. Day-to-day changes in plant water potential at another site (data not presented) indicate that plant water potentials are responding to surface (0-40 cm) soil water but are largely independent of water table fluctuations. This suggests that oak species are fairly shallowly rooted in scrub and related communities. However, the different site orders for soil water content vs. plant water potential during predawn conditions suggest the effective rooting depth for oaks extends well beyond 40 cm where soil was collected. This is also consistent with the lack of correlations between surface (0-40 cm) soil moisture content and predawn water potential. In addition, direct uptake of fog or dew could modify plant water potential without affecting soils.

Site differences in plant water potential may also reflect soil differences that influence vegetation, for example differences between yellow sands supporting sandhill and white sands supporting rosemary scrub or scrubby flatwoods (Kurz, 1942). However, consistent differences in the physical and chemical properties of yellow vs. white sands have not been demonstrated (Laessle, 1958; Kalicz and Stone, 1984) and soil color could reflect fire frequency and past vegetation (Kalicz and Stone, 1984; Myers, 1985). Sandhill soils generally are slightly more fine-textured than adjacent scrub soils (Laessle, 1958). In this study, the sandhill sites are found on yellow Astatula sands, which are finer-textured than St. Lucie soils (Carter and Lewis, 1982). Sandhill soils may also have a higher organic matter content (Miller, 1950) and water-holding capacity (Mulvania, 1931). If additional water held by yellow soils can be taken up by oaks at sandhill sites, lower predawn water potentials could result. It is conceivable that rapid uptake of water from the sandhill soils would create non-significant differences in soil moisture content, or, as in the case of this study, a pattern of drier sandhill soils while plants in sandhills were less stressed. Additional study of soil moisture dynamics in these sites is needed, as well as measures of plant cover, which may affect competitive water uptake.

Species differences in plant water potential also do not correspond to distributions with respect to distance to the water table. *Q. inopina*, which dominates communities, such as scrubby flatwoods, that are relatively close to the water table, was intermediate in terms of predawn plant water potential. *Q. chapmanii*, which is well-represented in several plant communities, exhibited the lowest water potentials. These species patterns are consistent with midday water potentials measured at Archbold Biological Station (Denton, 1989).

Predawn water potential alone is not sufficient to describe drought adaptations. The fact that *Q. chapmanii* has the lowest water potential does not necessarily imply that it is more poorly adapted to drought stress than the other oak species. Adaptations to drought stress include the ability to either tolerate or avoid desiccation (Kramer and Kozlowski, 1979; Bahari et al., 1985; LoGullo and Salleo, 1988). A plant tolerant to desiccation may exhibit negative water potentials and yet high physiological activity and fitness. Current studies are under way to explore the mechanisms of drought tolerance and the implications of drought adaptations for plant fitness in Lake Wales Ridge communities.

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LITERATURE CITED

ABRAHAMSON, W. G. 1984a. Post-fire recovery of Florida Lake Wales Ridge vegetation. Amer. J. Bot. 71:9-21.

———— 1984b. Species response to fire on the Florida Lake Wales Ridge. Amer. J. Bot 71:35-43.

————, A. F. JOHNSON, J. N. LAYNE, AND P. A. PERONI. 1984. Vegetation of the Archbold Biological Station, Florida: An example of the southern Lake Wales Ridge. Florida Scient. 47:209-250.

ABRAMS, M. D. 1988a. Sources of variation in osmotic potentials with special reference to North American tree species. Forest Sci. 34:1030-1046.

———— 1988b. Comparative water relations of three successional hardwood species in central Wisconsin. Tree Phys. 4:263-273.

ANDERSON, D. J., P. STRICKER, S. WILLIAMS, AND P. ADAM. 1988. A postulated water availability gradient in a coastal landscape: an ecophysiological analysis. Funct. Ecol. 2:391-397.

ANDERSON, R. 1990. Illinois State University, Normal, IL. Pers. commun.

BAHARI, Z. A., S. G. PALLARDY, W. C. PARKER. 1985. Photosynthesis, water relations, and drought adaptation in six woody species of oak-hickory forests in central Missouri. Forest Sci. 31:557-569.

CARTER, L. AND D. LEWIS. 1982. Archbold Biological Station Soil Legend and Descriptions. USDA Soil Conservation Service. Unpublished Report.

DENTON, S. 1989. Biological Research Associates, Tampa, FL Pers. commun.

HINCKLEY, T. M., J. P. LASSOIE, AND S. W. RUNNING. 1978. Temporal and spatial variations in the water status of forest trees. Forest Sci. Monogr. 20:1-72.

HUCK, R. B. 1987. Plant communities along an edaphic continuum in a central Florida watershed. Florida Scient. 50:111-128.

JOHNSON, A. F., W. G. ABRAHAMSON, AND K. D. MCCREA. 1986. Comparison of biomass recovery after fire of a seeder *(Ceratiola ericoides)* and a sprouter *(Quercus inopina)* species from south-central Florida. Amer. Midl. Natur. 116:423-428.

KALICZ, P. J., AND E. L. STONE. 1984. The longleaf pine islands of the Ocala National Forest, Florida: a soil study. Ecology 65:1743-1754.

KRAMER, P. J. AND T. T. KOZLOWSKI. 1979. Physiology of Woody Plants. Academic Press, New York. 811 pp.

KURZ, H. 1942. Florida dunes and scrub, vegetation and geology. State of Florida, Geological Bulletin No. 23. Florida State Geological Survey. 153 pp.

LAESSLE, A. M. 1958. The origin and successional relationship of sandhill vegetation and sand-pine scrub. Ecolo. Monogr. 28:361-387.

LOGULLO, M. A., AND S. SALLEO. 1988. Different strategies of drought resistance in three Mediterranean sclerophyllous trees growing in the same environmental conditions. New Phytol. 108:267-276.

MILLER, R. B. 1950. Ecological comparisons of plant communities of the xeric pine type on sand ridges in central Florida. M.S. Thesis, Univ. Florida, Gainesville. 71 pp.

MULVANIA, M. 1931. Ecological survey of a Florida scrub. Ecology 7:528-540.

MYERS, R. L. 1985. Fire and the dynamic relationship between Florida sandhill and scrub vegetation. Bull. Torrey Bot. Club 112:241-252.

________ 1990. Scrub and high pine. Chapter 6. *In:* MYERS, R. L. AND J. T. EWEL (eds.). Ecosystems of Florida. Univ. Presses of Florida, Gainesville. *In press.*

________ AND D. L. WHITE. 1987. Landscape history and changes in sandhill vegetation in north-central and south-central Florida. Bull. Torrey Bot. Club 114:21-32.

ROMO, J. T. AND M. R. HAFERKAMP. 1989. Water relations of *Artemisia tridentata* ssp. *wyomingensis* and *Sarcobatus vermiculatus* in the steppe of southeastern Oregon. Am. Midl. Nat. 121:155-164.

ROY, J. AND R. LUMARET. 1987. Associated clinal variation in leaf tissue water relations and allozyme polymorphism in *Dactylis glomerata* L. populations. Evol. Trends Plants 1:9-19.

SCHOLANDER, P. F., H. T. HAMMEL, AND E. A. HEMMINGER. 1965. Sap pressure in vascular plants. Science 148:339-346.

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SOUTH FLORIDA SLASH PINE MORTALITY IN SEASONAL PONDS

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Abstract: *Two cohorts of south Florida slash pine seedlings and saplings that had invaded seasonal ponds were followed to determine mortality due to high water table or fire. The invasion of slash pines into seasonal ponds appears to be checked primarily by episodic high water tables, although fire can cause high mortality to pines in densely grass-covered seasonal ponds. Fire temperatures in dense grass-covered seasonal ponds were comparable to those attained in adjacent flatwoods.*

One of the most striking features of peninsular Florida's seasonal ponds is their distinct boundary with adjacent vegetation associations (Laessle, 1942; Hubbell et al., 1956; Abrahamson et al., 1984). This boundary is created by the transition from the vegetative associations of the surrounding communities containing saw palmetto, *Serenoa repens*, to species characteristic of seasonal ponds. For example, the horizontal stems of saw palmetto frequently grow down-slope from flatwoods toward seasonal ponds but stop to form an apparent flatwoods-seasonal pond boundary. This ecotone between vegetative associations suggests a lack of dynamic interaction between the species of these adjacent associations.

However, species of seasonal ponds (e.g., *Hypericum edisonianum*, Edison's St. John's Wort) frequently invade flatwoods, and certain flatwoods species (e.g., *Pinus elliottii* var. *densa*, south Florida slash pine) are common recruits in seasonal ponds. These rapid invasions suggest a dynamic equilibrium exists within these associations.

While one can frequently find cohorts of south Florida slash pine seedlings and saplings growing in seasonal ponds, it is relatively uncommon to see mature slash pine in this vegetative association. This observation suggests that either mortality to slash pines in seasonal ponds must be high and that it may occur episodically or slash pines may currently be invading seasonal ponds. However, periods of time with conditions favorable to south Florida slash pine germination and seedling growth may be punctuated by conditions that cause pine mortality. There are several potential sources of slash pine mortality in seasonal ponds including (1) waterlogging of below-ground organs due to periodically high water tables and (2) heat kill due to fire. This study was intended to explore the degree to which south Florida slash pine mortality in seasonal ponds can be caused by high water tables and/or fire.

Methods—On 19 January 1977, the basal diameters and heights of 59 south Florida slash pine saplings [32 in a cutthroat grass *(Panicum abscissum)*-dominated seasonal pond and 27 in a saw palmetto-dominated flatwoods] were measured and the plants were permanently tagged for future censuses. These trees were burned by a prescribed fire on 21 January 1977 and sapling survival was determined on 7 May 1977 and 20 January 1978.

A second cohort (N = 23) of south Florida slash pine seedlings and saplings growing in a

Hypericum edisonianum-dominated seasonal pond was measured for height and was permanently tagged on 19 January 1978. A census of this cohort on 29 January 1979 discovered an additional 17 seedlings bringing the seasonal pond's total slash pine population to 38. This population was recensused on 16 January 1980.

Fire temperatures were measured in a third, moderately dense grass-*Hypericum edisonianum* dominated seasonal pond and saw palmetto-dominated flatwoods on 25 January 1980 using 38 × 51 × 1.3 mm aluminum plates coated with strips of Tempil™ heat-sensitive paints. Melting points of these heat-sensitive paints ranged from 66°C to 1093°C in intervals of 28°C to 56°C.

Monthly precipitation data were obtained from the records of the Archbold Biological Station. These data were recorded at a location less than 3 km from all study sites.

RESULTS—The most striking result of this study was the high degree of south Florida slash pine mortality recorded in a seasonal pond between January of 1979 and 1980 (Table 1). Over 92% of all existing pines died during this 12 month period. In addition, there was no recruitment during this period, whereas the previous 12 month interval had seen the recruitment of 17 seedlings with the loss of only 2 pines (8.7%).

TABLE 1. Survival, recruitment, and mortality of south Florida slash pine, *Pinus elliottii* var. *densa*, in a seasonal pond. Individually tagged pines were censused in January of 1978, 1979, and 1980.

	Living Trees			Recruitment		Mortality	
	1978	1979	1980	1978-79	1979-80	1978-79	1979-80
Population Size (N)	23	38	3	17(44.7%)	0(0%)	2(8.7%)	35(92.1%)
Mean Height ± SD (cm)	6±2.8	9±6.6	58±4.5	6±3.1	—	—	—

The 3 pines that survived to 1980 were appreciably taller than the mean for the cohort (Table 1). All but one pine exhibited growth between January of 1979 and 1980. South Florida slash pines recorded as living in 1979 but dead in 1980 added an average of 15.1±14.1 (S.D.) cm of height during this interval whereas pines surviving to 1980 grew an average of 34.0±3.1 cm. These results suggest that mortality occurred after much of the 1979 growth had occurred (i.e., late summer or autumn) and that survival may be related to greater height and/or more vigorous growth. Survival could result from either more favorable locations within the seasonal pond or genotypes better adapted to seasonal pond conditions.

It is likely that the ground-water table was appreciably higher during 1979-1980 compared to levels during the previous several years. Hurricane Frederick and other September precipitation provided 35.9 cm of rain on top of the 26.9 and 32.4 cm of precipitation during July and August, respectively. Precipitation during July, August, and September of 1979 totaled 95.2 cm, whereas the 18-year (1972-1989) mean precipitation for those 3 months was only 55.8±14.6 cm. Total July, August, and September precipitation during the previous four summers when pine recruitment was likely occurring was about average with 51.2, 52.7, 60.3, and 55.8 cm for 1975, 1976, 1977, and 1978, respectively. Precipitation for 1979 totaled 154.7 cm which was greater than the 18-year (1972-1989) average of 128.7±17.3 (standard deviation) cm. At the time of the January 1980 census, water was standing in many nearby seasonal ponds that were not filled with water during previous Januaries. Although it is not possible to prove that these unusually high summer 1979 precipitation levels caused the high pine mortality observed in a seasonal pond, there is a correlation between these events.

In the above case of open *Hypericum edisonianum*-dominated ponds, it is unlikely that fire would cause appreciable slash pine mortality because of low fuel loads. However, seasonal ponds with high grass coverage burn completely and can burn at temperatures high enough to cause pine mortality. A cohort of 32 south Florida slash pine seedlings and saplings, growing in a seasonal pond densely covered with cutthroat grass, suffered 78.1% mortality in the one-year period following a prescribed burn (Table 2). This mortality level was similar to that (77.8%) recorded in an adjacent saw palmetto-cutthroat grass flatwoods area in which pine is a constituent of variable density. Survival at both sites was size-dependent with taller pines surviving best, especially in the seasonal pond. Survivors averaged 155 and 89 cm in height while the entire cohorts had means of 112 and 82 cm for the seasonal pond and flatwoods, respectively (Table 2).

TABLE 2. South Florida slash pine height and basal diameter for two marked cohorts of saplings censused prior to and following a January 1977 fire. Post-fire censuses were conducted on 7 May 1977 and 20 January 1978.

	Pre-fire			Post-fire			
Association	Population Size, N	Mean Height ± S.D., cm	Mean Basal Diameter ± S.D., cm	Population Size, N	Mean Height ± S.D., cm	Mean Basal Diameter ± S.D., cm	Mortality %
Seasonal Pond	32	112 ± 54.5	3.6 ± 1.57	7	155 ± 27.5	5.1 ± 1.06	78.1%
Flatwoods	27	82 ± 34.9	2.9 ± 1.22	6	89 ± 57.7	4.0 ± 1.72	77.8%

Temperatures during fire can reach levels comparable to adjacent flatwoods if grass coverage levels are high. Temperatures of at least 316C were recorded at 35-40 cm above ground level in a moderately dense grass-covered seasonal pond (N = 2). In a nearby flatwoods that was densely vegetated with saw palmetto, cutthroat grass, and wire grass *(Aristida stricta)*, temperatures ranged from 66°C to 482°C between ground level and 70 cm above ground (mean = 282°C ± 119, N = 11).

DISCUSSION—Invasion of south Florida slash pine into open seasonal ponds appears to be checked primarily by episodic high water tables. Observation of a cohort of slash pines in an open, *Hypericum edisonianum*-dominated seasonal pond suggests that pines invade during years of low to normal precipitation but are eliminated during years of higher than average rainfall. Perhaps also important is the timing of precipitation relative to slash pine growth. Excessive winter rains, for example, may promote sapling mortality due to water-logging of roots.

High water table appears to be the primary factor causing mortality to slash pines that invade seasonal ponds. Yet, slash pine germination and establishment is highly dependent on adequate precipitation and soil moisture. It may seem ironic that the Archbold Biological Station saw remarkably high levels of south Florida slash pine germination during November 1979-January 1980, the same time interval that recorded high sapling mortality in seasonal ponds (W. G. Abrahamson and C. E. Winegarner, personal observations).

Fire plays a role in limiting the establishment of slash pines in topographically higher seasonal ponds and in those with dense grass cover just as it does in flatwoods. Densely grass-covered ponds frequently burn vigorously with the vigor of fires positively related to grass cover. However, prescribed burns at the Archbold Biological Station frequently skip seasonal ponds since many of these ponds are ringed with a bare sand zone that functions as a natural fire break (Abrahamson et al., 1984).

Although this study offers very limited fire-temperature data, it is clear that dense grass cover in seasonal ponds can produce temperatures high enough to kill or stress young south Florida slash pine. This may be especially true when fire effects are coupled with droughty or high precipitation conditions. Saplings under water stress due to low or high rainfall both before and after fires may exhibit high rates of mortality.

The heights of the apical buds and the thickness of bark of young south Florida slash pine may influence the degree of mortality due to fire. Fire-induced mortality of slash pines was size-dependent both in this study of seedlings and saplings and one of mature trees (Abrahamson, 1984).

Thus, mortality of slash pine seedlings and saplings in seasonal ponds is likely dependent on high water tables but may also be influenced by several variables including fuel loads, plant size, pre- and post-fire precipitation, and water table conditions both prior to and subsequent to fire.

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LITERATURE CITED

ABRAHAMSON, W. G. 1984. Species responses to fire on the Florida Lake Wales Ridge. Amer. J. Bot. 71:35-43.

———, A. F. JOHNSON, J. N. LAYNE, AND P. A. PERONI. 1984. Vegetation of the Archbold Biological Station, Florida: an example of the southern Lake Wales Ridge. Florida Scient. 47:209-250.

HUBBELL, T. H., A. M. LAESSLE, AND J. C. DICKINSON, JR. 1956. The Flint-Chattaoochee-Appalachicola region and its environments. Bull. Florida State Mus. Biol. Sci. 1:1-63.

LAESSLE, A. M. 1942. The plant communities of the Welaka area. Univ. of Florida Publ. Biol. Sci. Ser. IV(1).

Florida Scient. 54(2):80-83. 1991.
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REVIEW

Eugene Garfield, *Science Literacy, Policy, Evaluation, and Other Essays,* ISI Press, 3501 Market Street, Philadelphia, 1990, Pp. xiv + 451. Price: $35.00

AVID readers of *Current Contents*® will recognize these essays as reprints of *Current Comments*®, the essays that the author has produced on a weekly basis without interruption since 1972. (They appeared irregularly starting in 1962). The whole series has appeared as the collected work, *Essays of an Information Scientist*, and this is the eleventh volume in the series. The essays are noteworthy for their wide range, the thoroughness of their documentation, and their readability. My favorites from this volume include: "Chronobiology," "All Sorts of Warts—Separating Fact from Fiction", and "Journal Proliferation and the Popular Press." Other essays also describe aspects of information science, not surprising in view of the title and the fact that the author is well known as the inventor of the *Science Citation Index.* I have enjoyed reading Dr. Garfield's essays each week, and in this volume and others, the essays are preserved, beautifully printed on sturdy stock. If you have been an avid reader, reading the essays again is like meeting old friends. If you haven't read them, you have been deprived, but it isn't too late.—Dean F. Martin, University of South Florida, Tampa.

WINTER KILLS OF *TILAPIA MELANOTHERON* IN COASTAL SOUTHEAST FLORIDA, 1989.

Joel W. Snodgrass, Brevard County, Office of Natural Resources Management, 2575 North Courtenay Parkway, Merritt Island, Fl. 32953.

ABSTRACT: During December, 1989 low temperatures resulted in the thermal mortality of large numbers of Tilapia melanotheron *in manmade aquatic habitats on central Merritt Island, Florida. Estimates of the number of fishes killed at four locations ranged from 23 to 2662. All locations were characterized by shallow water (<1.5 m), low salinities ($\leq 7‰$), and narrow connections (culverts or canals) to the Indian River lagoon system.*

THE warm climate of Florida facilitates the establishment of exotic fishes. As Shafland (1986) points out "more exotic fishes are established in Florida than in any other state." The most important range limiting factor for established exotic species in Florida is temperature, since most fishes established in Florida are native to the tropics and are not tolerant of low temperatures. Shafland and Pestrak (1982) determined the mean lower lethal temperature of *Tilapia melanotheron* to be 10.3°C and predicted that the species could extend its range to latitude 29° (Daytona Beach). *T. melanotheron* has been established in the Tampa Bay area since 1958 (Buntz and Manooch, 1969, cited by Dial and Wainright, 1983) and in the Indian River lagoon system since 1980, where it is thought to be rapidly expanding its range (Dial and Wainright, 1983). In recent documented thermal mortality events in the Indian River lagoon system *T. melanotheron* has not been reported as being affected (Gilmore, et al., 1978; Snelson and Bradley, 1978). This paper reports the thermal mortality of large numbers of *T. melanotheron* during the winter of 1989 and describes the habitat that the species was occupying when killed.

METHODS—The Indian River lagoon system is located on the east coast of Florida and has been described in detail by other authors (Gilmore, et al., 1978; Mulligan and Snelson, 1983; Snelson and Bradley, 1978).

On January 5, 1990 four locations where fishes had been killed as a result of exposure to low temperatures during the period of December 23 through December 26, 1989 were visited. At each location fishes were counted and identified to species. At two locations estimates of the number of fishes killed were obtained by counting all fishes. Estimates for the other two locations were made by counting fishes along randomly selected 10 m sections of shoreline. These numbers are used to calculate an average number of fish/m and a total number of fish killed at each location.

RESULTS AND DISCUSSION—All fishkills were in manmade lakes and canals in central Merritt Island (latitude 28°). The first location was a small canal that opened into the east side of Sykes Creek. The second location was two lakes that connect to New Found Harbor through a culvert and short canal just north of the Merritt Island Airport runway. The third location was a lake in the Merritt Ridge housing development at the intersection of Cone road and SR 3. A culvert connects this lake to the Indian River. The fourth location is a series of interconnected residential canals near the 2000 block of South Tropical Trail (SR3). A canal connects this sytem to the south end of Newfound Harbor. All sample locations exhibited low salinities ($\leq 7‰$) and shallow depths (≤ 2m) on January 5, 1990.

Estimated numbers of fishes killed at the four locations were 23 (0.1 fish/m), 69 (0.2 fish/m), 512 (1.2 fish/m), and 2662 (1.4 fish/m). Air temperature at the Melbourne Airport dropped below 0°C on December 23, 24, and 25, 1990 (NOAA, 1989). Lagoon populations were apparently not affected in 1989.

The small volume of water at the sample locations and limited access to the larger and deeper lagoon waters may have resulted in lengthened exposure to low temperatures in these habitats when compared with lagoon waters. Salinity can influence lethal temperatures (Stauffer et al., 1984) for *T. melanotheron* and may have played a role in buffering the effect of temperature in lagoon waters also.

The lack of quantitative data on exotic fish populations makes assessing the effects of the 1989 winter kill on *T. melanotheron* populations impossible. However, the large number of *Tilapia melanotheron* killed in this cold event indicates that this species is rapidly expanding its range into fresh waters that are accessible by the Indian River lagoon system. This data also indicates that lagoon populations of this species are more protected from the effects of cold weather than populations in shallow freshwater habitats at comparable latitudes.

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LITERATURE CITED

BUNTZ, J., AND C. S. MANOOCH. 1969. A brief summary of the cichlids in the south Florida region. Unpub. Rept. for the Florida Game and Fresh Water Fish Commission (Cited by Dial and Wainright, 1983).

DIAL, R. S., AND S. C. WAINRIGHT. 1983. New distributional records for non-native fishes in Florida. Fla. Scient. 46(1):8-15.

GILMORE, R. G., L. H. BULLOCK, AND F. H. BERRY. 1978. Hypothermal mortality in marine fishes of south-central Florida, January, 1977. Northeast Gulf Sci. 2:77-97.

MULLIGAN, T. J., AND F. F. SNELSON, JR. 1983. Summer-season populations of epibenthic marine fishes in the Indian River Lagoon system, Florida. Fla. Scient. 46:250-276.

NOAA. 1989. Climatological data, Florida, December 1989. 93(12):10.

SHAFLAND, P. L. 1986. A review of Florida's efforts to regulate, assess and manage exotic fishes. Fisheries 11(2):20-25.

_________, AND J. M. PESTRAK. 1982. Lower lethal temperatures for fourteen non-native fishes in Florida. Envir. Biol. Fish. 7(2):139-156.

SNELSON, F. F., JR., AND W. K. BRADLEY, JR. 1978. Mortality of fishes due to cold on the east coast of Florida, January, 1977. Fla. Scient. 41(1):1-12.

STAUFFER, J. R., JR., D. R. VANN, AND C. H. HOCUTT. 1984. Effects of salinity on preferred and lethal temperatures of the blackchin tilapia, *Sarotherodon melanotheron*. Water Resources Bull. 20(5):771-775.

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OBSERVATIONS OF ASSOCIATIONS BETWEEN SEAGRASS BEDS AND MANATEES IN EAST CENTRAL FLORIDA

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Abstract: *During winter and spring of 1986 a preliminary study to assess effects of large concentrations of manatees feeding on a* Syringodium filiforme *dominated seagrass flat in the north Banana River was conducted as part of the long term environmental monitoring program at the Kennedy Space Center, Florida. Aerial surveys were used to collect manatee distribution and abundance information. Data on the distribution, percent cover and biomass of seagrasses were collected from 50 randomly selected locations. Six exclosure cages paired with open plots (2.25 m^2) were used to assess grazing affects. Percent cover of* Syringodium filiforme *at sites open to feeding was greatly reduced (90%) by manatees cropping the blades and mean shoot biomass was significantly ($p = 0.03$) reduced. Manatee distribution data showed a positive correlation with* Syringodium filiforme *($r = 0.65$) and* Halodule wrightii *($r = 0.50$), and a negative correlation with the macroalgae,* Caulerpa prolifera *($r = 0.74$).*

The Cape Canaveral area, Brevard County, Florida represents the northern limit of major subtropical seagrass meadows in lagoonal waters along the east coast of the United States. During a study of seagrass distribution in Florida, Phillips (1960) found no *Syringodium filiforme* (manatee grass) north of Cape Canaveral. Submerged aquatic vegetation (SAV) distribution and mapping studies conducted in the Canaveral area in 1986, extending from the Banana River north to Ponce de Leon Inlet, revealed the presence of a few isolated patches of manatee grass (Provancha, unpublished data). This same area is part of the range of two large marine herbivores, the green turtle, *Chelonia mydas,* (Ehrhart, 1979) and the manatee, *Trichechus manatus* (Hartman, 1979). Lewis and coworkers (1987) suggested that herbivory affects phenotypic expression of plant morphology and plays a determining role in abundance and distributions of plants.

Green turtles, although common nesters on the Cape Canaveral beaches, are rarely found in the northern Banana River (Ehrhart, 1979; 1988). Manatees, however, are commonly seen along seagrass beds in the northern Banana River on the Kennedy Space Center (KSC) from spring through fall (Hartman, 1979; Irvine et al., 1979; Shane, 1983; Breen, 1981, and Provancha and Provancha, 1988). The largest aggregations of manatees in this area are predictably sighted in spring of each year as animals migrate away from their winter refuges (Shane, 1983). Unprecedented numbers of manatees (200 to 300) were observed in the northern Banana River in spring of 1985, 1986, and 1987 (Provancha and Provancha, 1988). One area that was preferred by manatees during those years had a large meadow of seagrass that was dominated by *Syringodium.* The predictable influx of manatees to this grassbed provided us the opportunity to make observations on the effects that a large concentration of manatees have on seagrass species composition, percent cover, and biomass.

Various studies have collected data on the feeding ecology of several vertebrate species in seagrass beds with limited success (Mortimer, 1981; *Chelonia mydas;* Anderson and Birtles, 1978; Heinsohn et al., 1972, 1977, *Dugong dugong;* Ogden, 1976, 1980; Thayer et al., 1984, Various taxa). Despite difficulties involved in aquatic field research, a few studies have begun to quantify manatee feeding rates and impacts on food resources (Packard, 1981, 1984; Bengston, 1983; Best, 1981; Campbell and Irvine, 1977; Ledder, 1986; Lomolino and Ewel, 1984; Etheridge et al., 1985; Lefebvre et al., 1988). Hartman (1979) observed manatees feeding only on the blades of seagrass, while Zieman (1982) and Packard (1981, 1984) reported manatees rooting in grassbeds, ingesting entire plants. It was our intent to quantify, on a small scale, the effects of large, temporary concentrations of free-ranging manatees on an isolated *Syringodium* dominated seagrass bed by using exclusion cages in an area that is effectively a manatee sanctuary and is not populated by other large herbivorous species. In addition, we compared manatee and SAV distribution data collected as part of the ongoing monitoring program at KSC to provide information on possible total system effects produced by the spring influx of manatees.

METHODS AND STUDY AREA—Aerial survey data of manatee abundance and distribution collected from spring and summer of 1985 (Provancha and Provancha, 1988) were reviewed to determine which section of the northern Banana River study area had consistently high numbers of manatees feeding on SAV. The surveys indicated that more manatees were generally found north of NASA Causeway in an area closed to public boating. Based on the distribution data in the closed area, a seagrass flat (1.3 km^2) on the western edge of a large dredged basin (0.8 km^2) referred to as Area 4B was selected for the 1986 feeding and exclusion study (Fig. 1). Area 4B was frequented by at least 109 manatees in the spring of 1985. The SAV was dominated by manatee grass but also contained *Halodule wrightii*, shoal grass, and the attached macro-alga, *Caulerpa prolifera.* The sediments were a mix of sand and shell that formed a firm surface.

In late February, six temporary stations were positioned in the SAV beds near the western rim of the 13-m deep dredged basin in the study area. Each station consisted of two circular sampling plots (each 2.25 m^2) located in what visually appeared as a homogeneous patch of vegetation. One plot was caged to exclude manatees, and the other, approximately 15 m away, was left open to grazing. The center of each plot was marked with a 5-cm diameter PVC stake. Exclosures were formed by cutting 1.4 m wide animal fencing into 5.3 m lengths. Each length was rolled and the ends joined together with plastic tie wraps, then set upright to form a circular pen. The 5 × 10-cm mesh size was deemed an acceptable compromise that would prevent entanglement of manatees as well as minimize affects on water flow over the vegetation or entrapment of large quantities of floating debris. We were concerned about possibly confusing manatee rooting activity described by Zieman (1982) and Packard (1981) from stingray *(Dasyatis sabina)* activity scars as these rays are prevalent in the area. The mesh size of the cages also excluded rays, eliminating that variable. The exclosures were anchored to the river bottom with concrete reinforcing steel (re-bar). Several cages located in water deeper than 1.2 m had lids constructed of the fencing material to eliminate potential intruders over the rim. The large mesh was assumed to have a negligible effect on light availability.

Within each circular plot, percent cover for each species was determined following methods of Daubenmire (1968), and mean blade height of *Syringodium* was determined within a 25 × 50-cm plot frame at six positions around the PVC stake. A buffer zone of 50 cm separated the cage walls from the plot frame positions. Blade height was determined to the nearest centimeter from the sediment to the blade tip using a meter stick. The diver measured a range of blade heights within the plot frame and then estimated an average height for each of the 6 positions in each circular plot. Water depths were recorded at the central stake for each circular plot. Snorkeling or SCUBA was employed in sampling.

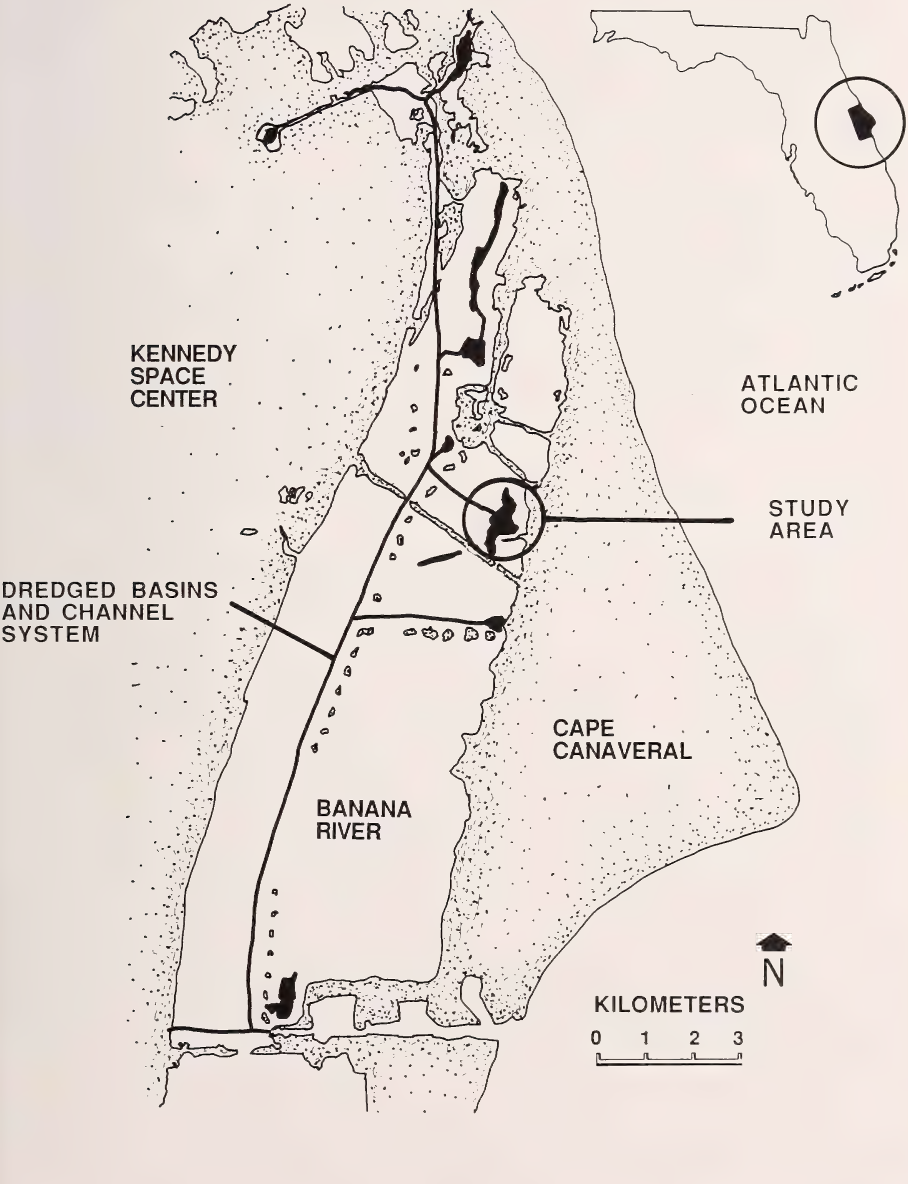

Fig. 1. Northern Banana River, Brevard County, Florida including the manatee feeding study area and delineation of channels and dredged basins.

Data were collected in February during the cold period prior to the predicted manatee spring immigration and again in April after large numbers of animals had been feeding in the area. Determination of data collection times was facilitated by manatee aerial surveys that were conducted monthly over the study area (Provancha and Provancha, 1988). The February and April sample periods are referred to as the pre-grazing and post-grazing periods, respectively.

The April sampling included collection of four biomass samples (above and below ground) at each exclosure and open plot. Biomass samples were collected using a benthic coring device that yielded a cubic sample, 15 cm on a side. The samples were rinsed in water and separated into above ground parts (shoots) and below ground parts (roots). Samples were oven dried for 48 hours at 60°C, then weighed to the nearest 0.01 g. One set each of above ground biomass sample for *Syringodium*, *Halodule,* and *Caulerpa* was collected in area 4B spring 1987 for proximate analyses to determine nutritional composition. The blades were clipped at just above the sediment layer and placed in plastic bags for transport to the laboratory. The *Syringodium*, *Halodule*, and *Caulerpa* blades (60 g each) were oven dried at 60°C for 48 hours. Analyses were performed by Nutrition International Inc. of New Jersey.

Underwater photos were taken of the plots. In addition, aerial photos taken from an elevation 1220m were obtained in January, February, April, and May to further document pre- and post-feeding conditions.

Additional data related to manatee-seagrass associations were collected in 1987 during investigations of 50 randomly selected stations or grids in the northern Banana River. The 50 stations were a subsample of 249 possible grids that had been overlayed on a map of the river. Each grid was 610 m × 533 m in size. A loran-C was used to find the approximate center of the grids selected for sampling. Eighteen of the 50 stations were located north of the NASA Causeway while the remaining 32 were to the south. Within each grid, percent cover for each species was determined for 18 random samples using the previously described plot frame methods. Three above ground biomass samples were also collected from each of the 50 sites. The 18 sites north of NASA Causeway were sampled in February and again in May. Data were expected to better quantify the overall distribution, abundance, and biomass of SAV in the area and when overlaid on manatee distribution data, provide a tool for evaluating potential SAV species and manatee associations.

Data analyses included development of simple descriptive statistics, graphical display, bivariate correlations, and hypothesis testing. Statistical comparisons using continuous variables such as biomass and *Syringodium* blade height were conducted with t-tests. All tests involving the categorical percent cover data were conducted with non-parametric procedures such as the Mann Whitney U-test. Originally, the mensurative exclosure experiment consisted of a randomized block design with six paired treatment blocks allowing for the application of Wilcoxon's signed-ranks test. Destruction of the exclosure at Station 5 by manatees and an obvious lack of grazing (treatment effect) at Station 1 reduced the usable data to a sample size of four precluding application of the Wilcoxon test (Hurlbert, 1984). Thus, only graphical comparisons were made with the percent cover data from the exclosure study.

Pre-grazing comparisons of *Syringodium* percent cover and seagrass blade height for six samples from each of the remaining four paired treatment blocks were made to define ranges of natural variability and similarities of replicate site selections. Post-grazing comparisons of percent cover, blade height, and shoot and root biomass were made to test the null hypothesis that the treatment (manatee grazing) had no effect on the target parameters in this highly utilized grass bed. Relationships between manatee abundance, percent coverages of SAV, and water depth were evaluated with the Spearman Rank Correlation procedure. Information from 25 of the random grid stations, located in the flight path of the aerial survey route, were included in the analysis. The bivariate correlation table was generated using total manatee abundance observed in each grid for seven surveys (January to March) in addition to mean water depth $(n=3)$ and mean percent coverage of *Halodule*, *Syringodium*, and *Caulerpa* data estimated for each grid using 18 random plot frame readings collected in February.

TABLE 1. Aerial survey results for the months January through May 1986 in the northern Banana River.

Date	Total Manatees Counted	Total Manatees in Area 4B	Mean Air Survey Temp
Jan 14	1	0	17.7°C
*Feb 19	85(7)	19(2)	21.6°C
Mar 25	139(19)	82(11)	21.6°C
*April 8	297(22)	206(14)	25.0°C
May 20	67(8)	26(3)	26.1°C

*Vegetation data collected February 22-24 and April 10-11.
( ) indicate number of calves.

RESULTS—The 1986 pre-grazing vegetation plot data inside the exclosures and at open sites were collected on February 22-24 after a February 19 aerial survey revealed a considerable number of manatees (85) in the KSC area earlier than expected (see Table 1). Visual inspection of the area indicated that manatees had not been recently feeding in the study site prior to sample collection. Sampling of the study plots for post-grazing effects was conducted on April 10-11 after an aerial survey indicated that 206 manatees were occupying Area 4B.

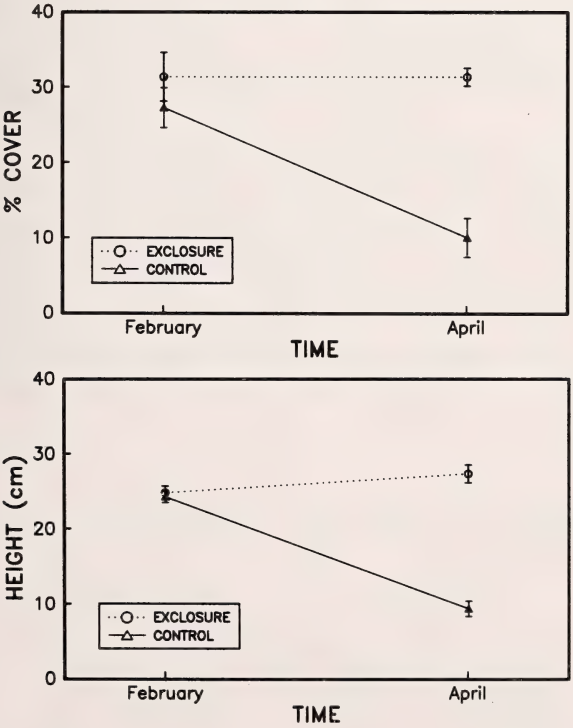

FIG. 2. Mean density (percent cover) and mean blade height with 95% confidence limits for the two sample periods (pre/post-grazing) for five stations for *Syringodium filiforme*.

Field observations suggested that pre-grazing conditions in the SAV at the exclosure and open sites were similar. Density (percent cover) and blade height were similar at all sites (Fig. 2). For the four usable paired treatment blocks, there was no significant difference in the blade height measurements ($p = 0.64$) which ranged between 18 and 29 cm prior to exclosure.

Comparisons between seasons at the exclosure and open sites showed dramatic changes in SAV. Post-grazing blade height in the exclosures increased only slightly to a range of 25 to 31 cm. Post-grazing blade heights at sites affected by manatee feeding activities were reduced to a range of between 5 and 9 cm. Inside the exclosures, there was no obvious change in the density of *Syringodium.* Density of *Syringodium* at the open sites was dramatically reduced as a result of manatee grazing (Fig. 2). The most noticeable change appeared as a cropping of the plant blades just above the meristem. Underwater inspection of the area revealed very little of the rooting activity described by Packard (1981). The grazing activity was patchy in the study area with the exception of Station 1 where apparently none occurred. Aerial photographs taken in February and April also showed no obvious changes in the northern section of the study area near Station 1. Changes in the density of SAV at study sites 3, 4, 5, and 6 were obvious in the photographs. The exclosure at Station 5 was severely damaged, apparently crushed by manatees after the first sampling and became an area open to feeding. Station 5 was excluded from post-grazing analyses.

In the exclosures, the ratios of the various species remained almost constant with the exception of the order of magnitude decline in *Halophila,* a minor component of this SAV community (Fig. 3). At the grazed sites, the significant decrease in the percent composition of *Syringodium* was related to a proportional increase in the percent of heavily cropped area where no blades were seen (referred to as bare ground). *Halophila* decreased in density as it did inside the exclosure sites. *Halodule* increased slightly in density between February and April. The dramatic increase in the bare ground category was directly attributable to the reduction in blade height of *Syringodium* as a result of the manatee grazing activities. Mean shoot biomass at the grazed stations was significantly ($p = 0.03$) lower than mean shoot biomass from inside the exclosures (Table 2).

TABLE 2. Summary data for the April 1986 above and below ground biomass samples (dry weights) collected at each of ten plots. Data expressed as mean ± standard deviations from 225 cm^2 plugs, and extrapolated to g/m^2.

	Grazed N = 20		Ungrazed N = 20	
	$g/225\ cm^2$	g/m^2	$g/225\ cm^2$	g/m^2
Shoots:[a]	1.57 ± 2.10	69.8	3.03 ± 2.11	134.5
Roots:	5.09 ± 2.25	225.9	4.27 ± 1.78	189.5

[a] *Root to Shoot Ratio* 3.3:1-Grazed
Root to Shoot Ratio 1.4:1-Ungrazed

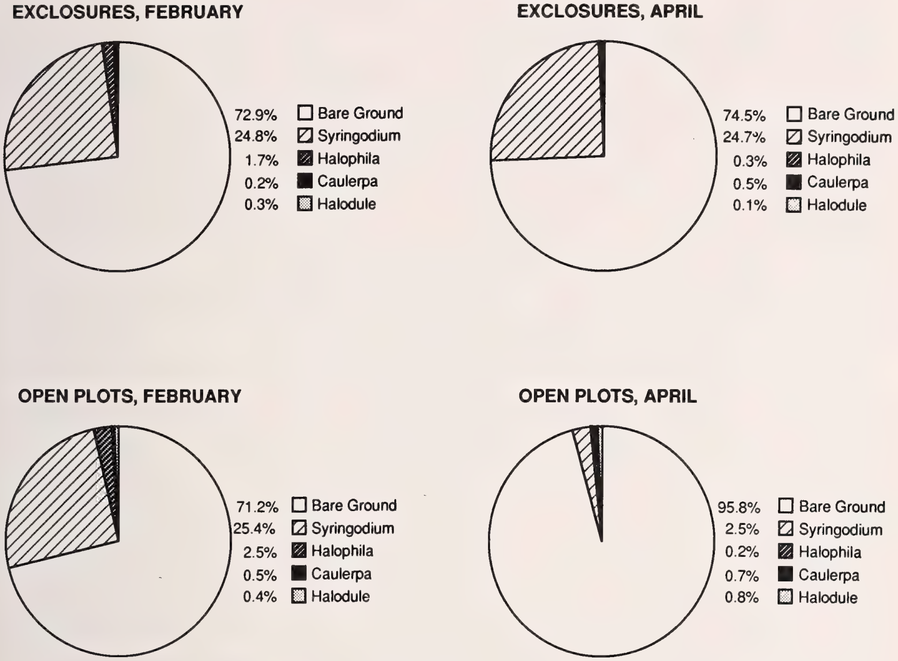

FIG. 3. General trends in vegetation changes after grazing. Mean species densities recorded at the exclosure and open plots before (February) and after (April) the large aggregations of manatees entered the study area. Exclosures and open plot data do not include Station 5 (destroyed by manatees) and Station 1 (no feeding activity occurred there).

Manatee distribution in the northern Banana River displays a high degree of aggregation with more than 80% of the animals generally observed along the north of the NASA Causeway (Provancha and Provancha, 1988). Manatee abundance was positively correlated with *Syringodium* and *Halodule* and negatively correlated with *Caulerpa* (Table 3). *Halodule* displayed a strong negative correlation with depth while *Caulerpa* showed an opposite trend. There was a large significant negative correlation between *Syringodium* and

TABLE 3. Results of Bivariate Spearman Rank Correlation Analyses of manatee abundance data and percent composition of submerged aquatic vegetation species in the northern Banana River during Spring 1987. Lower value of each pair indicates the significance probability of the correlation.

	Depth	Manatees	*Halodule*	*Syringodium*	*Caulerpa*
Depth	1.000				
	0.000				
Manatees	−0.248	1.000			
	0.231	0.000			
Halodule	−0.737	0.501	1.000		
	0.000	0.011	0.000		
Syringodium	0.188	0.653	0.213	1.000	
	0.368	0.000	0.307	0.000	
Caulerpa	0.404	−0.742	−0.067	−0.565	1.000
	0.045	0.000	0.000	0.003	0.000

TABLE 4. SAV densities observed in winter and spring of 1987 at grids 64-69 in the Area 4B grassbed. Densities expressed as percent cover.

	1987	
Species	Winter Densities (N = 72) Mean ± SD	Spring Densities (N = 72) Mean ± SD
Halodule	8.8 ± 12.2	5.2 ± 9.5
Syringodium	15.3 ± 20.2	25.9 ± 30.9
Caulerpa	0.2 ± 0.7	0.2 ± 1.8

Caulerpa and a small significant negative correlation between *Halodule* and *Caulerpa.* These results indicate that *Syringodium* and *Caulerpa* generally do not occur together in our study area.

Results of aerial surveys indicated that 12 of the 50 randomly selected grids were consistently frequented by manatees with peak densities ranging from 9.3 to 83.8 manatees/km^2. A comparison of SAV species composition at these 12 stations with the remaining 38 stations in the Banana River was made using the Mann Whitney U-test. At these 12 stations, *Halodule* and *Syringodium* were significantly more abundant than at the remaining 38 sites ($p<0.0001$ for both taxa). *Caulerpa* displayed an opposite trend with significantly lower densities being observed at the 12 stations ($p<0.0001$). Analyses of the 1987 random grid data that occurred in Area 4B (See Table 4) indicated that percent cover for the two most common species *(Halodule and Syringodium* were not significantly different in mid-February ($p = 0.128$) but percent cover for *Syringodium* was significantly higher than *Halodule* in late May ($p<0.0001$).

TABLE 5. Nutritional analysis of samples of three prominent submerged aquatic plants from study Area 4B.

	SPECIES		
	Halodule wrightii	*Syringodium filiforme*	*Caulerpa prolifera*
Moisture, %	3.79	3.72	7.27
Protein, %	11.95	11.02	16.67
Fat, %	1.25	0.61	2.46
Ash, %	35.20	30.19	26.96
Fiber, %	14.67	12.75	18.31
Carbohydrate, %	33.14	41.71	28.33
Calories (cal/g)	192	216	202
Potassium (mg/g)	1512	2771	151
Calcium (mg/g)	7313	4232	4261
Magnesium (mg/g)	930	819	545
Iron (mg/g)	47.1	24.9	121.7
Sulfur (mg/g)	646	797	769
Copper (mg/g)	0.32	0.28	0.39
Zinc (mg/g)	0.87	0.88	0.61
Manganese (mg/g)	25.5	18.6	16.2
Phosphorus (mg/g)	134	123	122
Molybdenum (ppm)	0.12	0.19	0.29

Proximate composition of blades (Table 5) falls within the ranges reported by Dawes and Lawrence (1979) for *Thalassia* blades relative to percentages of protein, fat, ash, and fiber. The species of particular interest, *Syringodium*, had the lowest percentages of protein, fat, and fiber and the highest percent carbohydrate, and the highest levels of potassium (mg/g).

DISCUSSION—Our observations of manatee grazing impacts on seagrasses are in contrast to those of Zieman (1982) and Packard (1981). Although Packard did observe blade cropping, she characterized manatee feeding as a predominantly rooting behavior, removing over 90% of the total biomass. We noted only occasional rooting scars and a preponderance of grazed or cropped trails. Trails were typically about 45cm wide, extending from 1 to several meters long. The blade heights in the trails were 5 to 10cm which contrasted sharply with the surrounding vegetation where blade heights were generally greater than 25cm. A few areas were uniformly "mowed" rather than forming trails. The grazing versus rooting behavior may be attributed to differences in substrate characteristics that affect the ease of rooting or to animals feeding during different SAV growth phases. Manatees ingesting entire plants at Hobe Sound were overwintering (Packard, 1981) and may have required the additional calories found in the root matter or perhaps winter seagrass blades are less nutritious. Bengston (1983) noted a seasonal difference in manatee consumption rates of freshwater vegetation in the St. Johns River with the lowest rates occurring in spring. He suggested that the winter vegetation was less nutritive than spring growth and therefore larger quantities had to be consumed. The manatees immigrated to our study area and fed during the early spring when water temperatures begin to rise and *Syringodium* is entering a rapid growth phase. Packard (1981) also suggested that feeding behavior (rooting versus grazing) might be influenced by grassbed density. She noted random grazing in sparse grassbeds and rooting in more dense patches. The Area 4B dry weight biomass values for blades (131 g/m^2) are indeed lower than those reported by Packard (414 g/m^2). Constant feeding by manatees in the manner described by Zieman (1982) and Packard (1981) would suggest a long term effect on the SAV beds since rhizosphere disturbance can jeopardize recovery (Thayer, et al., 1984). These effects are currently being monitored by Lefebvre and coworkers (1988) at Hobe Sound. Based on our 1986 observations rooting does not appear to be a problem for grass beds at our study sites.

Manatee distributions at KSC in the spring suggest a selection for *Syringodium* and *Halodule* dominated areas for feeding (Table 3). There may also be an avoidance of the zones containing large amounts of the alga, *Caulerpa prolifera*. A homogenous bed of *Caulerpa* surrounding a dredged basin is located west of the 4B grassbed. Manatees were rarely observed there and may have been responding to the anti-herbivore compounds found in *Caulerpa* (Ogden, 1976). Counter to this *Caulerpa* avoidance interpretation, the negative correlation between the distribution of *Syringodium* and *Caulerpa* could suggest that, if the animals prefer and actively seek *Syringodium* beds, they would not encounter much *Caulerpa*. Lipkin (1975) reported finding three species of *Caulerpa* in one of six dugong *(Dugong dugong)* specimens from the Red Sea. However, of the identifiable contents in various parts of the alimentary tract, the *Caulerpa* constituent represented $<1\%$ of the total. Hartman (1971) reported algal consumption by manatees to be incidental during feeding on vascular plants. Stomach content analyses of dead manatees salvaged over several years in Brevard County (approximately 50 samples) indicated that *Caulerpa* was not an uncommon food item but was found in relatively small amounts (Beck, 1989).

Hartman (1971) described indiscriminate selection of feeding sites by some Crystal River manatees while others repeatedly returned to a particular feeding area. Our efforts did not involve observation of individuals and so we cannot address this aspect of feeding ecology, but perhaps ongoing research by the U.S. Fish and Wildlife Service Sirenia Project (Lefebvre, et al., 1988) will reveal similar findings.

At present, we do not know long-term effects of the large numbers of manatees grazing on the *Syringodium* beds. Manatee grazing may benefit seagrasses by aiding in dispersal when plant fragments escape ingestion or through nutrient increases from fecal matter scattered over the beds. The protein content of seagrasses tend to be highest in fresh leaves and leaf bases. Thayer and coworkers (1984) reported feeding by grazing rather than complete plant uprooting stimulates new growth and could thereby enhance the nutritional value of the vegetation for the succeeding grazing event. Bjorndal (1980) described green turtles maintaining grazing plots in *Thalassia* beds and found higher N contents in grazed areas versus ungrazed areas. However, Thayer and coworkers (1984) reported repetitive, intense grazing of seagrass blades does stress the plant in terms of leaf width, leaf production, and rhizome storage capabilities. Green turtles eventually abandon their grazing plots (Ogden, 1980) which may coincide with the nutritional degradation of the plants as described above. A large percentage (ca 75%) of the aggregation of manatees that arrive at KSC each spring disperse from the area by May (Provancha and Provancha, 1988). This massive, although incomplete, immigration may be a response similar to that described for green turtles, although unlikely when estimates of the feeding impacts in this area are calculated.

We can speculate about the potential of area 4B seagrass bed to continue to support large groups of manatees. To do this, we simplify and assume the seagrass biomass values as well as manatee consumption rates remain constant spatially and temporally in the seagrass bed. Heinsohn and coworkers (1977) estimated that an adult dugong will consume 5.6 kg of seagrass (dry wt) per day. Bengston (1983) reported an estimated 33.2 kg per day (wet wt), while Etheridge and coworkers (1985) reported consumption rates of Florida manatees, feeding on hydrilla, to be approximately 33.4 kg per day (wet wt). Using Packard's (1981) 1 g wet wt to 0.18 g dry wt, we can convert the wet consumption rate 33.2 kg/day (Bengston, 1983) to 5.9 kg/day (dry). Dividing this consumption rate by the 131 g/m^2 biomass value for the blades in our study area yields a grazed area of 45.6 m^2/day per manatee. This study area

(1,755,000 m^2) is then divided by 45.6 m^2/day yielding 38,486 days which is divided by 206 manatees (the maximum count for area 4B) yielding 186 grazing days per manatee available. A large percentage of the animals generally migrate away from the study area and northern Banana River after about 60 days, thus consuming only about 30% of the standing stock of blades, at a time when seagrass resources are far from exhausted and are rapidly being replaced.

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LITERATURE CITED

ANDERSON, P. K. AND A. BIRTLES. 1978. Behavior and ecology of the dugong, *Dugong dugon* (Sirenia): observations in Shoalwater and Cleveland Bays, Queensland. Australian Wildl. Res. 5:1-23.

BECK, C. 1989. Pers. Comm., United States Fish and Wildlife Service, Denver Wildlife Research Center, Gainesville, Florida.

BENGSTON, J. L. 1983. Estimating food consumption of free-ranging manatees in Florida. J. Wildl. Manage. 47:1186-1192.

BEST, R. C. 1981. Foods and feeding habits of wild and captive Sirenia. Mam. Rev. 11:3-29.

BJORNDAL, K. A. 1980. Nutrition and grazing behavior of the green turtle *Chelonia mydas*. Mar. Biol. 56:147-154.

BREEN, L. L. 1981. Report on Banana River manatee surveys March 1980 through March 1981. Merritt Island National Wildlife Refuge. April. Contract report to John F. Kennedy Space Center. Unpublished. 11 pp.

CAMPBELL, H. W. AND A. B. IRVINE. 1977. Feeding ecology of the West Indian manatee *Trichechus manatus* Linnaeus. Aquaculture 12:249-251.

DAUBENMIRE, R. 1968. Plant communities. A textbook of plant synecology. Harper & Row, Publisher, New York. 300 pp.

DAWES, C. J. AND J. M. LAWRENCE. 1979. Effects of blade removal on the proximate composition of the rhizome of the seagrass *(Thalassia testudinum)* Banks Ex Konig. Aquatic Botany 7:255-266.

EHRHART, L. M. 1979. Threatened and endangered species of Kennedy Space Center, Vol. 4, pt. 1, Marine turtle studies. National Aeronautics and Space Administration, Contract No. NAS10-8986, KSC TR 51-2. 106, 301 pp.

________ 1988. University of Central Florida, Orlando, pers. commun.

ETHERIDGE, K., G. B. RATHBUN, J. A. POWELL AND H. I. KOCHMAN. 1985. Consumption of aquatic plants by the West Indian manatee. J. Aquatic Plant Manag. 23:21-25.

HARTMAN, D.S. 1971. BEHAVIOR AND ECOLOGY OF THE FLORIDA MANATEE *Trichechus manatus latirostris* (Harlan), at Crystal River, Citrus County. Ph.D. dissertation, Cornell University, New York. 285 pp.

________ 1979. Ecology and behavior of the manatee *(Trichechus manatus)* in Florida. Am. Soc. Mam. Spec. Publ. Ser. 5:1-153.

HEINSOHN, G. E. AND W. R. BIRCH. 1972. Foods and feeding habits of the dugong, *Dugong dugong* (Erxleben) in Northern Queensland, Australia. Mammalia. 36:414-422.

________, J. WAKE, H. MARSH, AND A. V. SPAIN. 1977. The dugong *(Dugong dugong)* in the seagrass system. Aquaculture 12:235-248.

HURLBERT, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecol. Monogr. Vol. 54, No. 2, p. 187-211.

IRVINE, A. B., M. D. SCOTT, AND S. H. SHANE. 1979. A study of the West Indian manatee *Trichechus manatus*, in the Banana River and associated waters, Brevard County, Florida. Final Report of the John F. Kennedy Space Center, NASA, Kennedy Space Center, Florida. Contract CC-63426A. 49 pp.

LEDDER, D. A. 1986. Food Habits of the West Indian manatee in south Florida. M. S. Thesis. Univ. Miami, Miami, Florida. pp. 113.

LEFEBVRE, L. W., D. P. DOMINING, W. J. KENWORTHY, D. E. MCIVOR, AND M. E. LUDLOW. 1988. Appendix B. Manatee grazing impacts on seagrasses in Hobe Sound and Jupiter Sound, January-February 1988. Unpublished. pp. 1-18 plus figures. *In:* KENWORTHY, W. J., M. S. FONSECA, D. E. MCIVOR, AND G. W. THAYER (eds.) The Submarine Light Regime and Ecological Studies of Seagrasses in Hobe Sound, Florida. 1988 Annual Report. NMFS, NOAA, Beaufort, North Carolina.

LEWIS, S. M., J. N. NORRIS, AND R. B. SEARLES. 1987. The regulation of morphological plasticity in tropical reef algae by herbivory. Ecology 68:636-641.

LIPKIN, Y. 1975. Food of the Red Sea dugong (Mammalia, Sirene) from Sinai. Israel J. Zoo. 24:81-98.

LOMOLINO, M. V. AND K. C. EWEL. 1984. Digestive efficiencies of the West Indian manatee *(Trichechus manatus)*. Florida Scient. 47:176-179.

MORTIMER, J. A. 1981. The feeding ecology of the West Caribbean green turtle *(Chelonia mydas)* in Nicaragua. Biotropica 13:49-58.

OGDEN, J. C. 1976. Some aspects of herbivore-plant relationships on Caribbean reefs and seagrass beds. Aquat. Bot. 2:103-116.

_________ 1980. Faunal relationships in Caribbean seagrass beds. Pp 173-198. *In:* Handbook of Seagrass Biology, an ecosystem perspective. PHILLIPS, R. C. AND C. P. MCROY (eds.). Garland STPM Press, New York.

PACKARD, J. M. 1981. Abundance, distribution and feeding habits of manatees *(Trichechus manatus)* wintering between St. Lucie and Palm Beach Inlets, Florida. Report prepared for USFWS Contract No. 14-16-0004-80-105. 142 pp.

_________ 1984. Impact of manatees *Trichechus manatus* on seagrass communities in eastern Florida. Acta Zool. Fenn. 172:21-22.

PHILLIPS, R. C. 1960. Observations on the ecology and distribution of the Florida seagrasses. Prof. Pap. No. 2, Fla. Board Conserv. 2:1-72.

PROVANCHA, J. A. AND M. J. PROVANCHA. 1988. Long-term trends in abundance and distribution of manatees *(Trichechus manatus)* in the northern Banana River, Brevard County, Florida. Mar. Mam. Sci. 4:323-338.

SHANE, S. 1983. Abundance, distribution and movements of manatees *(Trichechus manatus)* in Brevard County, Florida. Bull. Mar. Sci. 33:1-9.

THAYER, G. W., K. A. BJORNDAL, J. C. OGDEN, S. L. WILLIAMS, AND J. C. ZIEMEN. 1984. Role of larger herbivores in seagrass communities. Estuaries 7:351-376.

ZIEMAN, J. C. 1982. The ecology of the seagrasses of South Florida: a community profile. U.S. Fish and Wildlife Service, Office of Biol. Serv., Washington, D.C. FWS/OBS-82/25. 158 pp.

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POLLEN WALL STRUCTURE IN THE GOLDEN SHRIMP PLANT, *PACHYSTACHYS LUTEA* NEES, ACANTHACEAE

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Abstract—*Electron microscopy is used to observe mature and immature pollen of the tropical golden shrimp plant,* Pachystachys lutea *Nees. It is in a diverse family (Acanthaceae), that includes many showy, flowering vines and shrubs. Mature* P. lutea *pollen are prolate (average 72 μm × 60 μm in size), isopolar, and tricolporate. Its ornate exine surface has a reticulate pattern composed of winding muroid ridges that extend from a punctate tectum to delimit polygonal luminoid areas. Muri are thicker in mature pollen. Two pseudocolpi (shallow furrows without pores) fuse at the polar ends of the pollen to form ellipses in the mescolpium. Circular pores are features of the colpi at their widest diameter. In the final stages of exine maturation, its ektexinous components change ratios, i. e., the tectum and foot layers become thicker and the columellar layer becomes thinner.*

The tropical golden shrimp plant, *Pachystachys lutea* Nees, is a member of the family Acanthaceae, tribe Graptophylleae (Raj, 1961). Almost half of its species (about 250 genera and 2500 species) of herbs and shrubs are monotypic (Cronquist, 1981). Representatives of Acanthaceae are widely distributed mainly in the tropics and may be found growing in open country, the edges of forests, and spaces in densely wooded areas (Ridley, 1930; Small, 1933). They are characterized by dehiscent, exploding capsules and eurypalynous pollen (Ridley, 1930; Erdtman, 1966; Cronquist, 1981). *Pachystachys lutea* often is planted as an ornamental shrub because it has showy, golden bracts that form a racemose inflorescence.

Ever since the recognition of Acanthaceae as a family, it has been a challenge for systematists to determine natural relationships within it. Its pollen, however, are noted for great variety of morphology and, therefore, are more or less considered in diagnoses of new species and "widely used by taxonomists for classification" (Erdtman, 1969; Hilsenbeck, 1990). Erdtman (1966) provided a general description of acanthacean pollen that includes the following characteristics that may be applied to *P. lutea:* isopolar, polyaperturate, 3-colpoidorate, and with pseudocolpi. One investigator, Raj (1961), provided an extensive light microscopy study of acanthacean pollen to substantiate and clarify morphological descriptions in earlier work. In that paper, he briefly described, but did not figure, *P. lutea;* it is the only pollen study of that species. In 1969, Ridgway and Skvarla noted that the scanning electron microscope offers even greater resolution of pollen wall surface and stratification than the light microscope and that, consequently, it may be more useful for systematic studies. Therefore, in this study of *P. lutea* pollen (mature and immature stages), scanning electron microscopy is employed to further elucidate its exine structure.

Materials and Methods—Pollen removed from anthers of immature dried buds and mature flowers were acetolyzed for electron microscopy in the usual manner according to Erdtman (1960). Samples for scanning electron microscopy (SEM) were coated with 300Å of gold/palladium and observed with ISI Super IIIA and ISI-DS 130 electron microscopes. Terminology for pollen morphology is according to Faegri and Iversen (1975).

Results and Discussion—*Pachystachys lutea* pollen in this study are bipolar, prclate (slightly elongate, 1.25:1), and average 72 × 60 μm in diameter when mature (Fig. 1A). Immature *P. lutea* pollen average 56 × 46 μm (Fig. 2A-C). The dimension and size of the pollen now described differ from that reported for this species by Raj in 1961. His pollen were slightly smaller (average 65 × 32 μm, 2:1) and he described them as more elongate (perprolate). Pollen now reported are tricolporate with almost circular pores (3-7 μm in diameter) in colpi with the greatest width 7.0 μm (Fig. 1A, 2A-B). The smooth foot layer of the ektexine is exposed in the colpi near pores. Two shallow, elongate furrows (colpoid streaks about 0.3-0.7 μm wide) are between the colpi, in the mescolpium as figured by Erdtman (1969) for another acanthacean species, *Anisacanthus abditus*. They are called pseudocolpi because they have no associated pores. Pairs of pseudocolpi anastomose near the pollen poles to describe ellipses between colpi (Fig. 1A, 2A-C). Pseudocolpi and colpi, where they narrow near the polar ends, are almost obscured by the smooth, broad muroid ridges of mature pollen. Muroid ridges (0.5-0.7 μm high in both mature and immature stages) form a winding, irregular reticulate pattern that delimits polygonal luminoid areas. In mature pollen, the luminoid areas are smaller (greatest diameter 2.5 μm, compared with 3.5 μm in immature pollen) because the muroid girth is broader (about 0.9 μm thick) than in immature pollen (0.5 μm) (Fig. 1A-B, 2A-D). The punctate luminoid

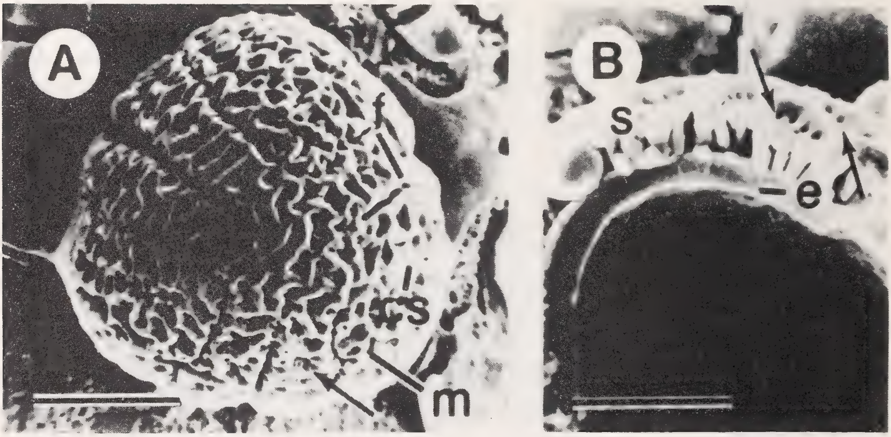

Fig. 1. A-B. Scanning electron micrographs of *Pachystachys lutea* mature pollen, (A) Polar view of pollen. Note furrows (colpi) (f), colpoid streaks (pseudocolpi) (cs), and thick muri (m) obscuring luminoid areas. Punctae (arrow) are visible at base of muri, bar = 10 μm, (B) Pollen wall fragment showing thin endexine (e) and thick sculptured layers (ektexine) (s) (foot layer contiguous with columellae, tectum, and muri). Note punctae (arrow) at base of muri bordering luminoid areas and on tectum surface (arrow), bar = 5 μm.

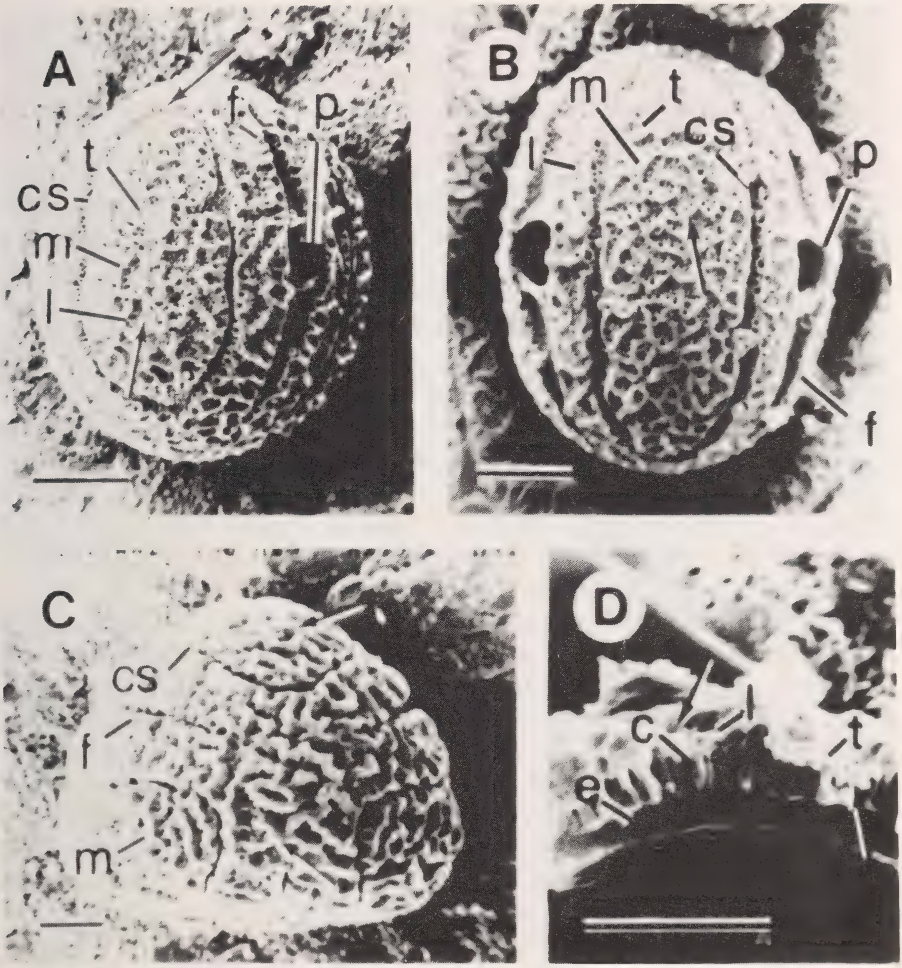

FIG. 2A-D. Scanning electron micrographs of immature *Pachystachys lutea* pollen, (A) Equatorial view of pollen showing pore (p) in furrow (colpus) (f), colpoid streaks (pseudocolpi) (cs), muri (m) forming a reticulate pattern around luminoid areas (l) where the punctate tectum (t) is exposed. Punctae (arrow) are visible at base of muri and on the tectum arrow, bar = 10 μm, (B) Equtorial view of pollen (slightly more developed than in previous figure) showing pores (p) in furrows (colpi) (f), and colpoid streaks (pseudocolpi) (cs) that describe ellipses. Note luminoid areas (l) with the punctate tectum (t) exposed and thicker muri (m). Punctae (arrow) are visible at base of muri and on tectum, bar = 10 μm, (C) Polar view of pollen (slightly more developed than in previous figures). Note furrows (colpi) (f), colpoid streaks (pseudocolpi) (cs), and thicker muri (m) obscuring tectum of luminoid areas (l). Punctae (arrow) are visible at base of muri, bar = 5 μm, (D) Pollen wall fragment showing exine stratification with thick endexine (e) and ektexine of foot layer contiguous with columellae (c) and tectum (t). Note punctae (arrow) at base of muri (m) bordering luminoid areas (l) and on tectum surface (arrow), bar = 5 μm.

floor is the upper surface of the tectum, and the punctae that penetrate it represent spaces between pillar-like elements of the columellar layer. Muri have several basal perforations that are smaller in mature pollen (about 0.23 μm compared with 0.35 μm in immature pollen) (Fig. 1B, 2A-D). In another species of *Pachystachys*, Raj (1961) referred to the basal openings as "marginal punctae." They appear to connect luminoid areas.

The wall (exine) of both mature and immature pollen is about 3 μm thick and composed of two layers, the ektexine and endexine. In mature pollen, the innermost, homogeneously dense endexine is 0.92 μm thick (this is about the same as in the immature stage). The ornamented outer ektexine is 2.21 μm thick and consists of a foot layer (0.22 μm thick), columellae (with pillar-like columellar elements about 0.93 μm long), and a tectum (0.46 μm thick) with muroid ridges extending from it (Fig. 1B, 2D). Columellar elements are about 0.42 μm diameter in mature pollen and slightly thinner (0.36 μm) in immature ones. Anastomosed columellar bases delimit the foot layer and the punctate tectum is formed of coalesced distal columellar heads. In immature pollen, where the columellar elements are thinner and longer (1.04-1.56 μm, average 1.25 μm), the tectum and foot layers are thinner, 0.26 μm and 0.14 μm respectfully. Columellar elements diminish in length as their bases and apices enlarge during maturation of the ektexine.

The Acanthaceae family is a challenge to taxonomists. Floral morphology has failed to provide enough information for reliable classification of genera and species. Furthermore, due to the great diversity in its pollen morphology, pollen studies, thus far, have made no significant contribution. Nevertheless, Raj (1961) concluded from his light microscopal investigation of Acanthaceae pollen, that characteristics of wall layers in conjunction with surface details were important as taxonomic tools. Since then, the scanning electron microscope has been applied to pollen morphological studies; it has a definite edge on clarification of exine surface features and stratification (Ridgway and Skvarla, 1969).

The only other study of *Pachystachys lutea* pollen was by Raj (1961) and he gave only a brief unfigured description as follows: 3-colporate, perprolate, and 65 × 32 μm. With the present SEM study, *Pachystachys lutea* now is known as a prolate form with well defined and measured exinous details. As with species examined by Hilsenbeck (1990) from another acanthacean tribe, Justicieae, this study may contribute to conclusions about generic relationships within Acanthaceae, its tribes, and certainly, the systematics of *Pachystachys*.

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LITERATURE CITED

Cronquist, A. 1981. An Integrated System of Classification of Flowering Plants. Columbia Univ. Press. New York.

Erdtman, G. 1960. The acetolysis method. A revised description. Sv. Bot. Tidskr. 54:561-564.

________. 1966. (1952 ed. reprint). Pollen Morphology and Plant Taxonomy. Hafner Publ. Co. New York.

________. 1969. Handbook of Palynology. Munksgaard. Copenhagen.

Fabgri, K. and J. Iversen. 1975. Textbook of Pollen Analysis. Blackwell. Oxford.

Hilsenbeck, R. A. 1990. Pollen morphology and systematics of *Siphonoglossa* sensu lato (Acanthaceae) Amer. J. Bot. 77:27-40.

Raj, B. 1961. Pollen morphological studies in the Acanthaceae. Grana Palynol. 3:1-153.

Ridgway, J. E. and J. J. Skvarla. 1969. Scanning electron microscopy as an aid to pollen taxonomy. Ann. Missouri Bot. Gard. 56:121-124.

Ridley, H. N. 1930. The Dispersal of Plants Throughout the World. William Clowes and Sons, Ltd. London.

Small, F. 1933. Manual of the Southeastern Flora. Univ. North Carolina Press. Chapel Hill.

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NEW RECORDS OF BUTTERFLIES FROM MONTSERRAT, WEST INDIES—*Albert Schwartz*, 10000 SW 84th St., Miami, FL 33173.

Abstract: *Five species of butterflies (four skippers, one nymphalid) are reported for the first time from the island of Montserrat.*

The rhopaloceran fauna of the Lesser Antillean island of Montserrat has been recently summarized by Schwartz and Jimenez (1982). They listed 38 species of butterflies, based not only on literature records (which are few) but also on collections made on the island by P. J. Richel and G. L. Blatt in 1980-81 (330 specimens in my collection and that of the Allyn Museum of Entomology).

Between 12 and 14 November 1987, Rose M. Henderson collected 80 specimens for me on Montserrat; her collection included one new island record. On 25-30 May 1990, Jose Escobio visited Montserrat on my behalf and took 126 specimens, including four new island records. The present report records these five lepidopterans not previously reported on the island. All specimens are in my collection.

In 1989, the eye of Hurricane Hugo passed directly over Montserrat. Henderson's field notes (1987) contrast sharply with those of Escobio (1990). Escobio reported the great reduction of flowers, which were virtually non-existent, and even where flowers still existed, there was little butterfly "action" (except for *Strymon a. acis* [Drury], 1973, on *Croton* sp. flowers). What previously was mesic broadleaf forest is now, due to the ravages of Hugo, denuded blow-downs; the trail to Great Alp Waterfall, which Henderson reported as passing from xeric lowlands to forested mesic uplands, no longer exists in its more upland portion, and one has to follow the rocky bed of the White River to reach the falls, which themselves no longer are surrounded by luxurious forest. What permanent effects such destruction may have on the butterflies of the island remains to be seen. It is remarkable that four of the five species newly reported from the island were taken about 8 months after Hurricane Hugo. This is not to imply that they are storm-driven vagrants; all are in excellent condition and almost certainly represent species previously overlooked on Montserrat.

HESPERIIDAE

Astraptes anaphus anausis (Cramer), 1777. This skipper has been recorded (Pinchon and Enrico, 1969) from Guadeloupe, Dominica, Martinique, St. Vincent, and Grenada; Montserrat is the island closest to Guadeloupe on the north, and the occurrence there of *A. a. anausis* is not unexpected. The specimen is a female; it was collected on Chance's Peak, 4.8 km SE Plymouth, 549-610 m, between 0800 and 1200 h under overcast conditions at a temperature of 29°C on 27 May.

The species appears to be rather uncommon on both the Greater and Lesser Antilles. It is uncommon on Hispaniola (Schwartz, 1989) and Puerto Rico (Comstock, 1944). *Astraptes a. anausis* also occurs on Jamaica where it is rare and local (Brown and Heineman, 1972) and on Cuba, where it is rare (Alayo and Hernández, 1987).

Ephyriades arcas arcas (Drury), 1773. In the Lesser Antilles, this species has been reported from St.-Martin, St.-Barthélémy, Antigua, Saba, St. Eustatius, and St. Christopher; thus it is known only from the northernmost islands in the Lesser Antillean arc, no further south than Antigua. Escobio, on 27-29 May, took five individuals as follows: one male, one female at Trant's, 2.4 km N Tuitt's, 6 m; one male at Bottomless Ghaut, 3.2 km NW Plymouth, 183-244 m; and two males on Chance's Peak, 549-680 m. The times of the collections were 0800-1700 h at temperatures of 29°C to 36°C.

Ephyriades brunneus dominicensis Bell and Comstock, 1948. The known Lesser Antillean range of this subspecies includes only the islands of Guadeloupe and Dominica. A single male, taken 26 May, 6.4 km NE Plymouth, 92-153 m between 1230 and 1300 h at a temperature of 32°C, extends the range of this skipper to the next island north of Guadeloupe.

Polites dictynna (Godman and Salvin), 1896. This skipper has been reported from St. Christopher, St. Vincent, the Grenadines, and Grenada. Escobio took two males on 26 and 28 May, one 6.4 km NE Plymouth, 1230-1300 h, 32°C, the other at Great Alp Waterfall, 4.8 km SE Plymouth, 0830-1030 h, at 31°C. The Monserrat records fill in the gap between St. Christopher in the north and St. Vincent in the south; the species should be looked for on the intermediate islands. That it has not been reported from Dominica, the Lesser Antillean island with the largest number of recorded species (49), is indeed strange.

NYMPHALIDAE

Marpesia petreus petreus (Cramer), 1779. This nymphalid is common on Puerto Rico and occurs in the Lesser Antilles on St. Christopher, Guadeloupe, Dominica, and St. Lucia. Thus the Montserrat specimen fills in the gap between St. Christopher and Guadeloupe. The single female was taken by Henderson on 14 November 1987, on the Great Alp Waterfall Trail along the White River, taking nectar from *Lantana ovatifolia* between 1200 and 1400 h. Note that this specimen, in fine condition, was taken long before the passage of hurricane Hugo.

ACKNOWLEDGMENTS—I am grateful to Mrs. Henderson and Mr. Escobio for their interest and activities on Montserrat.

LITERATURE CITED

ALAYO, D. P., AND L. R. HERNÁNDEZ. 1987. Atlas de las mariposas diurnas de Cuba (Lepidoptera: Rhopalocera). Editorial Cientifico-Técnica, La Habana: 148 pp + 49 pls.

BROWN, F. M., AND B. HEINEMAN. 1972. Jamaica and its butterflies. E. W. Classey, Ltd., London: 478 pp.

COMSTOCK, W. P. 1944. The insects of Porto Rico and the Virgin Islands. New York Acad. Sci. 12(4):421-622.

PINCHON, PÈRE R., AND P. ENRICO. 1969. Faune des Antilles françaises les papillons. M. M. Ozanne et Cie., Caen: 256 pp.

SCHWARTZ, A. 1989. The Butterflies of Hispaniola. Univ. Florida Press: Gainesville. 580 pp.

________, AND C. J. JIMENEZ. 1982. The butterflies of Montserrat, West Indies. Bull. Allyn Mus. 66:1-18.

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LIMITATIONS IN NEAREST NEIGHBOR TESTS OF DISPERSION AND ASSOCIATION[1]

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ABSTRACT: *Nearest neighbor tests of spatial dispersion using Monte Carlo procedures did not reveal pattern in a fabricated data set until applied separately to population subsets (i.e., males and females). An index of association was needed for map data from field experiments, so the statistic Kappa was evaluated and found inadequate for our purposes. Alternative statistics unfortunately are not available.*

NEAREST neighbor analyses have long been used in ecology for tests of dispersion (Clark and Evans, 1954; Thompson, 1956) and association (Pielou, 1961). The procedure has been to map locations of individuals (i.e., plants, animals, colonies, etc.), and then to designate each individual in turn as a base from which its nearest neighbor is determined. In tests of dispersion, distances between neighbors constitute the data, while in tests for association the relationships within pairs (e.g., male base-female neighbor, or species A base-species B neighbor) are tallied in contingency tables. Such methods may confirm simple patterns of dispersion and association but we have found them inadequate for testing patterns confounded by an independent variable with its own pattern of dispersion (i.e., an essential resource), or for making experimental comparisons involving differing degrees of association.

For tests of association Meagher and Burdick (1980) called attention to the problem that reciprocal nearest neighbors violate the assumption of independence for tests using chi-squared distributions. As an alternative, they properly advocated Monte Carlo trials to avoid unacceptable levels of Type I errors. The procedure offered by Meagher and Burdick (1980) is suitable for testing association within single plots, as might apply to single sampling or mapping efforts. However, a test statistic is also needed which can serve as an index to the degree of association and can allow experimental comparisons among plots. Fleiss (1981) described the Kappa-statistic as having desired characteristics. Kappa corrects for the association expected by chance alone, and takes on values between -1 and $+1$, with negative values indicating negative association, values near 0 indicating no association and positive values indicating positive association. The investigator may also choose to test for association between like-types (e.g., male-male) or unlike-types (e.g., male-female), depending upon the mechanisms hypothesized for the association. Despite these desirable attributes, the concern for Type I error from reciprocal nearest neighbors also exists for Kappa, so likewise, Kappa in this application is best tested with Monte Carlo trials.

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For tests of dispersion that same argument about reciprocal nearest neighbors violating independence would seem to apply. Furthermore, Monte Carlo trials are necessary in nearest neighbor tests for dispersion when the hypothesized pattern among individuals is confounded by a spatial pattern imposed by another factor. Such would be the case when locations of mapped individuals are, to some extent, dependent on a resource that is itself clumped or overdispersed.

We have been studying the behavioral ecology of benthic crabs associated with fixed refuges. One crab, *Pilumnus sayi*, occupies bryozoan colonies attached to seagrass blades (Lindberg, 1980; Lindberg and Frydenborg, 1980). Another, *Menippe mercenaria,* occupies burrows excavated primarily at the edges of seagrass banks or patchy rock outcroppings. *In situ* experiments in which refuge spatial patterns were manipulated have been conducted for *P. sayi* (Lindberg and Stanton, 1989) and *M. mercenaria* (Lindberg et al., 1990). Our experiments prompted the development of computer software for tests of dispersion and association with the above considerations in mind (McElroy and Lindberg, 1986).

These analyses were applied to real data (as in Lindberg and Stanton, 1989) but were found to be inadequate. To illustrate this claim most clearly, we created and analyzed a random data set and one containing obvious pattern as might be expected from mating system models (e.g. Orians, 1969; Borgia, 1979; Emlen and Oring, 1977; and Waltz, 1982). The simulation reported here demonstrates that adequate statistical procedures for testing biologically interesting spatial patterns are still needed.

METHODS—First, eleven rules were used to create a known, patterned data set: (1) Fifty refuge sites (the resource) of equal quality existed in a contagious spatial pattern (see Fig. 1) independent of their occupants (the consumers of interest in our analysis). (2) The occupancy rate approached 80% (therefore 40 occupants were needed). (3) Sex ratio among occupants was 1:1.5 (therefore 16 males and 24 females were needed). (4) The size range of males was arbitrarily set at 10.6 units to 20.0 units (increments of 0.6 units), while that of females was set at 10.3 units to 17.5 units (increments of 0.3 units), i.e., on average females are smaller than males. (5) All females occupied clustered refuge, and female size was evenly distributed among the clusters. (6) Larger females tended toward the center of clusters. (7) First quartile males, i.e., the largest, were evenly distributed among the clusters, and each was centrally located and occupied a refuge with a female. (8) All other occupants, male and female, occupied refuge sites alone. (9) Second quartile males were away from clusters but situated between clusters. (10) Third quartile males were evenly distributed among clusters but were solitary at the periphery, i.e., reflecting satellite tactics. (11) Fourth quartile males were away from clusters, but not necessarily near clusters.

Second, we created a data set without pattern among occupants by randomly assigning each occupant to a refuge site, i.e., retaining rules 1 through 4, while ignoring rules 5 through 11, and instead using a random numbers subroutine sampling with replacement.

The resultant map data (Figs. 1 and 2) were analyzed by comparing observed statistical values for each data set with their unique probability distributions derived from 1000 Monte Carlo trials, which employed sampling with replacement. Statistics calculated for dispersion were mean distances between neighbors for first, second, and third nearest neighbors. Dispersion among all occupants was considered first and then each sex was considered separately. The Monte Carlo trials used all occupants regardless of sex in the randomization of occupants among refuge sites, and simply used distances between males or distances between females for the sex-specific tests of dispersion.

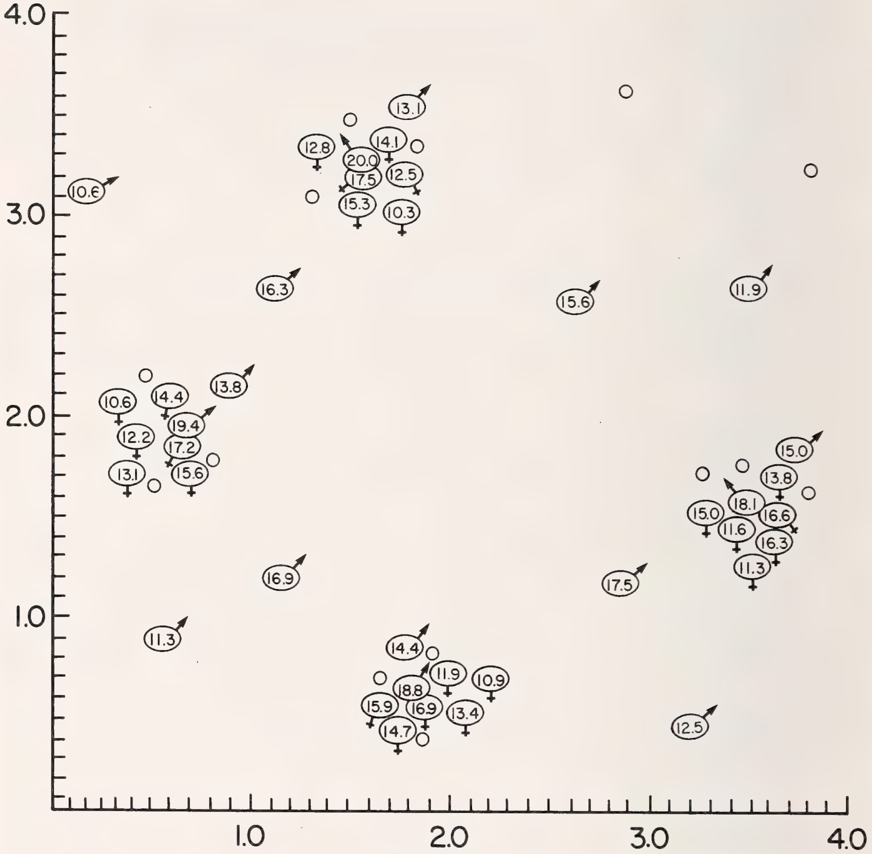

Fig. 1. Map of patterned data set contrived according to rules 1-11 stated in text. Coordinate scales are arbitrary. Ellipses indicate refuge sites occupied by either males or females (incorporating respective symbols). Intersecting ellipses indicate co-occupancy of a single refuge. Circles indicate vacant refuge. Numbers within ellipses represent sizes of occupants.

The statistic chosen for tests of association was the Kappa statistic calculated according to Fleiss (1981, p. 217) for the male-male cell in a 2 × 2 contingency table. Conceptually, Kappa is defined (Eqn 1):

$$\text{Kappa} = (I_o - I_e) \div (1 - I_e), \quad (1)$$

where I_o is an observed proportional value, I_e is the proportional value expected simply by chance, and $(1-I_e)$ is the maximum value possible for that difference between observed and expected. In practice, the cell and marginal frequencies of a contingency table were converted to proportions, and the values in one cell were evaluated relative to the remaining table. The male-male component of association was targeted, rather than male-female, because competition among males for access to mates is the mechanism reflected in the patterned data set (Fig. 1). Thus, $\text{Kappa}_{\text{(male-male)}}$ was expected to be significantly negative for the patterned data set and near zero for the random set.

Results—Figure 1 was generated from rules 1 through 11 above to depict a spatial pattern consistent with extreme resource defense polygyny and satellite male tactics. A random data set, derived from rules 1 through 4 and a random numbers subroutine, is mapped (Fig. 2).

TABLE 1. Observed mean distances between first, second, and third nearest neighbors (NN), and probabilities based on 1000 Monte Carlo trials, for data sets known to be patterned or random.

	1st NN	2nd NN	3rd NN
Patterned Data Set:			
All Occupants	0.259^{a}	0.323^{a}	0.378^{a}
Among Males	0.516^{b}	0.833^{b}	1.095^{a}
Among Females	0.167^{c}	0.220^{d}	0.268^{d}
Random Data Set:			
All Occupants	0.175^{a}	0.388^{a}	0.401^{a}
Among Males	0.268^{a}	0.555^{a}	1.132^{a}
Among Females	0.205^{a}	0.379^{a}	0.711^{a}

$^{a}p > 0.05$ for either 1- or 2-tailed tests
$^{b}p < 0.05$ for upper-tailed test
$^{c}p < 0.05$ for lower-tailed test
$^{d}p \leq 0.001$ for lower-tailed test

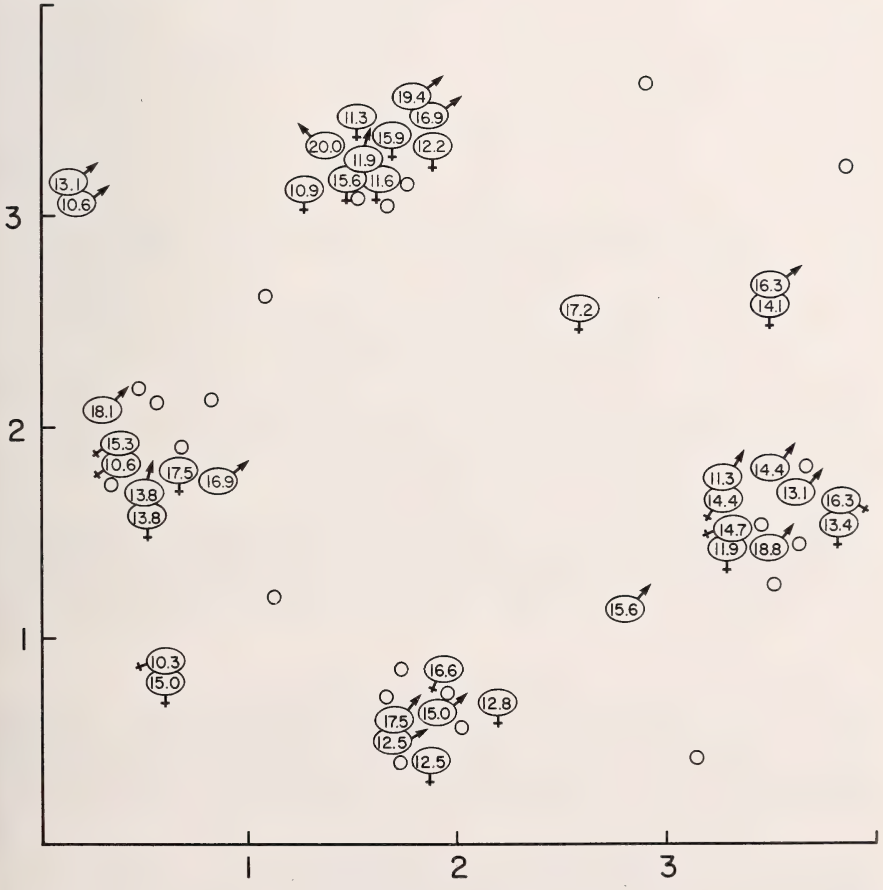

FIG. 2. Map of random data set contrived by ignoring rules 5-11 stated in text and instead using a random subroutine sampling with replacement. Symbols are the same as those used in Fig. 1.

TABLE 2: Observed Kappa (male-male) values for association among first, second, and third nearest neighbors (NN) for known patterned and random data sets, with probabilities based on 1000 Monte Carlo trials.

	1st NN	2nd NN	3rd NN
Patterned Data Set	0.0355*	0.1826*	−0.0983*
Random Data Set	0.0184*	−0.1417*	−0.2754*

*p > 0.05 for either 1- or 2-tailed tests

Significant spatial dispersion among occupants was detected for males and females separately in the patterned data set, while the random data set yielded no significance (Table 1).

Significant negative association or repulsion among males was not detected by using Kappa for first, second, or third nearest neighbors, for either the patterned or random data sets (Table 2).

DISCUSSION—The pattern among occupants, which was imposed by rules 1 through 11 as seen in Figure 1, was not detectable in nearest neighbor tests of dispersion until the sexes were considered separately. Clearly, tests of dispersion should be made at levels appropriate to mechanisms hypothesized to underlie an expected spatial pattern. Equally important, the obvious pattern was not at all detectable by the Kappa statistic for association, despite the appealing attributes of the Kappa statistic, as noted above. Reliance on Kappa would yield unacceptable levels of Type II error. In the instance of single plots (as shown in Figs. 1 and 2), the G-statistic Monte Carlo procedure used by Meagher and Burdick (1981) would no doubt yield appropriate results, but that procedure would not provide a standardized statistic for use in an experimental design for which differing degrees of association are expected among treatment groups (Lindberg and Stanton, 1989). The need for a statistic which summarizes the degree of association within a plot and which can be compared between plots led us to consider Kappa. That need, unfortunately, remains, and alternative statistics are not evident.

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LITERATURE CITED

BORGIA, G. 1979. Sexual selection and the evolution of mating systems. Pp. 19-80 *In:* M. S. Blum and N. A. Blum (eds). Sexual Selection and Reproductive Competition in Insects. Academic Press, New York.

CLARK, P. J. AND F. C. EVANS. 1954. Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology 35:445-453.

EMLEN, S. T. AND L. W. ORING. 1977. Ecology, sexual selection, and the evolution of mating systems. Science 197:215-223.

FLEISS, J. L. 1981. Statistical Methods for Rates and Proportions. John Wiley & Sons, New York. pp. 321.

LINDBERG, W. J. 1980. Patterns of resource use within a population of xanthid crabs occupying bryozoan colonies. Oecologia 46:338-342.

———— AND R. B. FRYDENBORG. 1980. Resource centered agonism of *Pilumnus sayi* (Brachyura, Xanthidae), an associate of the bryozoan *Schizoporella pungens*. Behaviour 75:235-250.

———— AND G. R. STANTON. 1989. Resource quality, dispersion and mating prospects for crabs occupying bryozoan colonies. J. Exp. Mar. Biol. Ecol. 128:257-282.

————, T. K. FRAZER AND G. R. STANTON. 1990. Population effects of refuge dispersion for adult stone crabs (Xanthidae, *Menippe*). Mar. Ecol. Prog. Ser. 66:239-249.

MCELROY, D. AND W. J. LINDBERG. 1986. Documentation for the Spatial Analysis System (SPAN) for resource use by animals. Florida Sea Grant Technical Paper, TP-42. Florida Sea Grant College Program, Gainesville, Florida.

MEAGHER, T. R. AND D. S. BURDICK. 1980. The use of nearest neighbor frequency analyses in studies of association. Ecology 61:1253-1255.

ORIANS, G. H. 1969. The evolution of mating systems in birds and mammals. Am. Nat. 103:589-603.

PIELOU, E. 1961. Segregation and symmetry in two-species populations as studied by nearest neighbor relationships. J. Ecology 49:255-269.

THOMPSON, H. R. 1956. Distribution of distance to nth neighbor in a population of randomly distributed individuals. Ecology 37:391-394.

WALTZ, E. C. 1982. Alternative mating tactics and the law of diminishing returns: the satellite threshold model. Behav. Ecol. Sociobiol. 10:75-83.

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Environmental Chemistry

AQUATIC PLANT AND RELATED INDICES

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ABSTRACT: *An index has been developed that indicates the magnitude of exotic aquatic plant coverage in Florida public waters. Data to develop the index came from the Florida Department of Natural Resources, Bureau of Aquatic Plant Management. The index is defined as the relative proportion (fraction x 1,000) of total water body acreage that is covered by two exotic aquatic plants, waterhyacinth [*Eichhornia crassipes *(Mart.) Solms] and hydrilla (*Hydrilla verticillata *(L.f.) Royle). For the years 1982-1988, the index values ranged from 42 to 53. The total waterbody acreage during that time period was about 1.3 million acres; 15 to 26% was covered with one aquatic plant or another, and the fraction covered by hydrilla and waterhyacinth was substantially smaller, about 4-5%. Two other indices are considered: total exotic aquatic plants and aquatic herbicides.*

Two exotic aquatic plants have attracted considerable attention in Florida and the southeastern United States over the years: hydrilla (*Hydrilla verticillata* (L.f.) Royle) and waterhyacinths [*Eichhornia crassipes* (Mart.) Solms]. Both are nuisance plants, and their excessive vegetation contributes to navigation and recreational problems in lakes and rivers as well as maintaining flood control in canals.

Hydrilla is a unique, perennial submersed aquatic plant with an interesting physiology (Van et al., 1976; Bowes et al., 1979; Barko, 1982; Sabol, 1987; Haller and Sutton, 1975). Its growth can dominate the surface of a lake within nine months after introduction. Hydrilla was introduced into Florida in the late 1950s, and it has been the major nuisance aquatic plant for the past two decades (Schardt and Nall, 1990).

Waterhyacinths (Penfound and Earle, 1948) were introduced into the St. Johns River in Florida in the 1890s, and have been a nuisance aquatic plant for much of this century. In 1982, waterhyacinth ranked third in abundance among aquatic plants; in 1988, it ranked twenty-fourth. To maintain the plant at this low level, a concerted action was required: herbicide treatment (Schardt and Nall, 1990) and control using imported organisms, including *Neochetina eichhorniae* Warner, *N. bruchi* Hustache and *Sameodes albiguttalis* Warren (Lepidoptera: Pyralidae) (Perkins, 1973; Goyer and Stark, 1984).

These two plants are not the only exotic aquatic plants in Florida. About 225,000 acres of aquatic plants were controlled in Florida public waters in 1988; about 85 percent of this control was for management of exotic plants. (Florida public waters included: public lakes, rivers, and those canals for which the Florida Department of Natural Resources provided funding for aquatic plant management for flood control. Neither private lakes without a public boat ramp, nor marshes and flood-plains were included in Florida public water.)

The indices presented here combine several parameters into equations that can serve as a guide to the magnitude of the aquatic plant problem in Florida or elsewhere. Three indices are presented: the Exotic (Critical and Total) Aquatic Plant Index and the related Aquatic Herbicide Index.

METHODS—Data were obtained from two sources of the Florida Department of Natural Resources Bureau of Aquatic Plant Management. Florida Aquatic Plant Surveys (Schardt and Nall, 1983 and 1990; Schardt, 1984, 1985, 1987) were used to obtain the basic data for calculating the Aquatic Plant Indices: These surveys, done by inspectors of the Bureau of Aquatic Plant Management of the Department of Natural Resources, list the plants encountered, the total acreage of each and percent of water bodies covered. Also given are data concerning change from previous years' coverage. Exotic Aquatic Herbicides Indices were calculated from amount and kind of herbicides used in a given year using data made available by Jeffrey D. Schardt and Jessie Van Dyke of the Bureau.

The Critical Exotic Aquatic Plant Index is defined (Eqn. 1) as the fraction of waters covered by hydrilla and waterhyacinth. The Total Exotic Aquatic Plant Index is also defined (Eqn. 2).

Critical Exotic Aquatic Plant Index =

$$\text{(fraction of area covered by hydrilla + waterhyacinth)} \times 10^3 \tag{1}$$

Total Exotic Aquatic Plant Index =

$$\text{(fraction of area covered by exotic plants)} \times 10^3 \tag{2}$$

A third index, the Critical Aquatic Herbicide Index was defined (Eqn. 3) as the percentage of the total herbicide weight used to control water hyacinth and hydrilla. The five herbicides considered were copper, Diquat®, Endothall, Fluridone, and 2,4-D(2,4-dichlorophenoxyacetic acid and appropriate salts).

$$\frac{\text{Weight of herbicide used to treat waterhyacinth/hydrilla}}{\text{Total weight of herbicide used in Florida public waters}} \times 100 \tag{3}$$

RESULTS AND DISCUSSION—Results of the Critical and the Total Exotic Aquatic Plant Indices are presented in Table 1. The values used to calculate the indices were based upon more recent total area data (Schardt and Nall, 1990). The areas involved in the system (State of Florida) are for public waters, and private lakes were omitted. Surveys in odd years were limited to waterhyacinth and hydrilla. During seven years of surveys up to 40 species of aquatic plants were included. As with most surveys, probably experience provides better data. About 30 exotic aquatic plant species were observed. Total number of aquatic plant species identified ranged from 129 to 146.

Surveys provide an outstanding listing of the 40 most abundant species. In a 1982 survey, for example, 44 species (mostly emergent, shoreline plants) were reported to cover less than ten acres (4.05 hectares) each. Hydrilla at that time covered 42,000 acres (17,004 hectares) and affected 40 of Florida's 67 counties. Part of this information is given in Table 1, but thoroughness of the surveys and the richness of the data are not represented.

The data in Table 1, however, show that the Critical Exotic Aquatic Plant Index has remained fairly constant over a seven-year period and ranged between 42 and 53. In 1982, waterhyacinth ranked third in abundance among all species; in 1988, it ranked 24th. These data indicate the success of an aggressive program of control, as discussed earlier by Joyce (1985). The constancy of the Critical Exotic Aquatic Plant Index also indicates that coverage by hydrilla is increasing.

TABLE 1. Calculation of the Exotic Aquatic Plant Index[a]

Year	1982	1983	1984	1985	1986	1987	1988
Waterbodies surveyed, acres	1,189,289	1,251,803	1,248,500	1,221,750	1,286,979	1,264,857	1,279,872
Fraction covered by							
Aquatic plants	0.151	0.26	0.245	—	0.261	—	0.266
Hydrilla	0.0354	0.0366	0.0371	0.0428	0.455	0.03895	0.0447
Waterhyacinth	0.00677	0.0160	0.00767	0.00455	0.00594	0.00494	0.00278
Hydrilla and Waterhyacinth	0.0422	0.0526	0.0448	0.0474	0.0515	0.0439	0.0475
All Exotics	—	0.0864	0.0969	—	0.0932	—	0.0832
Critical Exotic Plant Index	42.2	52.6	44.8	47.4	51.5	43.9	47.5
Exotic Aquatic Plant Index	70	87	97	—	93	—	83
Herbicide Index			85.5	81	79	87.7	
Number of species noted:							
Exotic	30	29	31	—	25	—	27
Total	129	154	162	—	146	—	137

[a]Data = Schardt, 1984-1987; Schardt and Nall, 1983, 1990.

Economics limited the amount of time that can be devoted to aquatic plant surveys, and the data for hydrilla and waterhyacinth, but not other plants, are available for all of the years 1982 to 1988. The Total Exotic Aquatic Plant Index has varied substantially over the years from a low of 70 to a high of 97, and it appears to be diminishing from the maximum. The surveys indicate that a relatively small number of exotic aquatics are responsible for much of the plant coverage of Florida public waters. In 1988, for example, about 35% of all the species (27 exotic species) covered 106,500 acres; three species covered 82,825 acres (Schardt and Nall, 1990). By comparison the same three species were the target species in about 70% of the 100,000 acres of Florida public waters that were managed for aquatic plants. Should we have revised the Critical Plant Index and limited it to the three most abundant species? We thought not because waterhyacinth and hydrilla data were available for every year since the major surveys began.

Exotic aquatic plants have spread, not only in Florida, but elsewhere in the United States (Langeland and Schiller, 1983; Webb et al., 1983; Rybicki et al., 1985). In Florida, the spread of hydrilla was not greatly retarded from 1980, large-scale control was virtually impossible, and he noted that in 1989 the acreage was 44,100 acres (17,854 hectares), the lowest coverage recorded since 1982. This is consistent with the values of Critical Exotic Aquatic Plant Index.

Related to the problem of exotic plants in Florida waters is another index. The Aquatic Herbicide Index is based upon the total weight of aquatic herbicides applied in a given year; the Critical Aquatic Herbicide Index is the fraction of the total herbicides devoted to the control of hydrilla and waterhyacinth. Though data should be available on a yearly basis, in practice, some data seem to be more accessible than others, and probably the more recent surveys have more reliable data. A plot of the Critical Aquatic Index as a function of Critical Aquatic Herbicide Index was linear ($r^2 = 0.898$) and is consistent with the direct relationship that one would anticipate (Fig. 1).

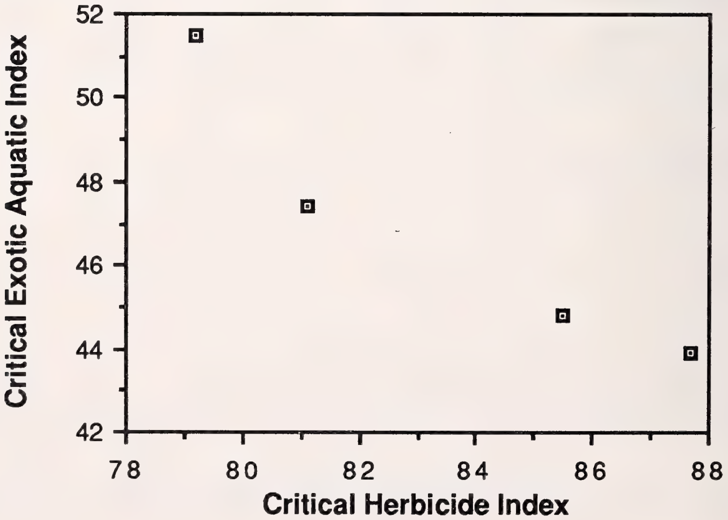

FIG. 1. Variation of Critical Exotic Aquatic Plant Index with Critical Herbicide Index 1984-1987 ($y = 0.82x + 115$; linear correlation coefficient, $r = 0.95$ ($P = 0.05$); $r^2 = 0.90$).

The Critical Aquatic Herbicide Index is flawed, however, because an increasing percentage of the total pounds of herbicide was devoted to treatment of critical exotic plants, and thus, we sought other correlations that might predict success. Funds expended for control should be a useful characteristic, and we used data provided by Schardt (1990b). The Critical Exotic Aquatic Plant Index was plotted as a function of dollars expended in a given year, and a slope of 1.4 ± 1.8 ($r = 0.4$) was obtained. Then the effect of lag time was included. The Critical Exotic Aquatic Plant Index was plotted as a function of funding for the previous year, and a slope of -2.1 ± 1.3 ($r = 0.8$) was obtained. There appears to be an inverse correlation of the Index with funds expended, but one may not see the effects of a given allotment of money and the treatment associated with it until the next year, thus the lag time. In addition, the effect of economies associated with treatment of larger areas (Schardt, 1990a) may affect the quality of the correlation. The correlation indicates that the use of herbicides is effective. If less money is available for herbicide purchase and application, one may anticipate an increase in the Critical Exotic Aquatic Plant Index with all the attendant problems.

Two uncertainties remain for consideration: herbaceous fish and water levels. Herbaceous fish can be effective in the management of hydrilla in Florida, though in appropriate circumstances. Their involvement could effect the agreement between the Critical Exotic Aquatic Plant Index and the Herbicide Index. A second factor is water level: we were reminded that with high water, the plant acreage can decrease noticeably; with low levels the apparent acreage in Lake Lochloosa and the Withlachoochee River increases noticeably (Haller, 1990). We believe that at present both factors may not be significant statewide, though they can surely be significant in local areas.

The future situation is complicated by two opposing factors: greater capacity for large-scale control and restoration of native vegetation versus a second factor of reduced funding for management. Aquatic plant management funding in Florida reached a maximum in 1986 when a total of $10 million in federal and state funding was available, but this was followed by a steady decline and in 1990 less than $5 million was available (Schardt, 1990a,b). This means that the Critical Exotic Aquatic Index will increase, of course, but it means that some major lakes in Florida will lose control of hydrilla maintenance, which has been hard won, and the frustration and disappointment will be understandable.

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LITERATURE CITED

Barko, J. W. 1982. Influence of potassium source (sediment vs. open water) and sediment composition on the growth and nutrition of a submersed freshwater macrophyte *Hydrilla verticillata* (L.f.) Royle. Aquatic Bot. 12:157-172.

Bowes, G., A. S. Holaday, and W. T. Haller. 1979. Seasonal variation in the biomass, tuber density, and photosynthetic metabolism of hydrilla in three Florida lakes. J. Aquat. Plant Manage. 17:61-65.

Goyer, R. A. and J. D. Stark. 1984. The impact of *Neochetina eichhorniae* on waterhyacinth in southern Louisiana. J. Aquat. Plant Manage. 22:57-61.

Haller, W. T 1990. Aquatic Plant Center, Univ. Florida, Gainesville, FL pers. comm.

_________ and D. L. Sutton. 1975. Community structure and competition between *Hydrilla* and *Vallisneria*. Hyacinth Contr. J. 13:48-50.

Joyce, J. C. 1985. Benefits of maintenance control of waterhyacinth. Aquatics 7(4):11-13.

Langeland, K. A. and D. Schiller. 1983. Hydrilla in North Carolina. Aquatics 5(4):8-14.

Perkins, B. D. 1973. Potential for waterhyacinth management with biological agents. Proc. Tall Timbers conf. Ecol. Anim. Control Habitat Manage. 4:53-64.

Penfound, W. T. and T. T. Earle. 1948. The biology of the waterhyacinth. Ecolog. Monogr. 18:448-472.

Rybicki, N., B. V. Carter, R. T. Anderson, and T. J. Trombley. 1985. *Hydrilla verticillata* in the tidal Potomac River, Maryland, and the District of Columbia, 1983 and 1984. U.S. Geol. Survey. Open-File Rep. 85-77, 1-25.

Sabol, B. M. 1987. Environmental effects of aquatic disposal of chopped hydrilla. J. Aquatic Plant Manage. 25:19-23.

Schardt, J. D. 1984. 1983 Aquatic Flora of Florida Survey Report. Bureau of Aquatic Plant Manage., Florida Department of Natural Resources, Tallahassee, FL.

_________ 1985. 1984 Florida Aquatic Plant Survey. Bureau of Aquatic Plant Manage., Florida Department of Natural Resources, Tallahassee, FL.

_________ 1986. 1985 Florida Aquatic Plant Survey. Bureau of Aquatic Plant Manage., Florida Department of Natural Resources, Tallahassee, FL.

_________ 1987. 1986 Florida Aquatic Plant Survey. Bureau of Aquatic Plant Manage., Florida Department of Natural Resources, Tallahassee, FL.

_________ 1990a. The state of aquatic plant management efforts at the end of the 1980s in Florida. The Bureau Bulletin 2 (1):2-3. (a quarterly publication of the Florida Department of Natural Resources, Tallahassee, FL).

_________ 1990b. Exotic plant control: a look back, a look ahead. Aquatics 12(1):6-8.

_________ and L. E. Nall. 1983. 1982 Aquatic Flora of Florida Survey. Bureau of Aquatic Plant Manage., Florida Department of Natural Resources, Tallahassee, FL.

_________ and L. E. Nall. 1990. 1988 Florida Aquatic Plant Survey. Bureau of Aquatic Plant Manage., Florida Department of Natural Resources, Tallahassee, FL.

Van, T. K., W. T. Haller, and G. Bowes. 1976. Comparison of the photosynthetic characteristics of three submersed aquatic plants. Plant Physiol. 58:761-768.

Webb, D. J., E. R. Burns, and A. L. Bates. 1983. Aquatic weed update—Tennessee Valley Authority. Aquatics 5(4):15-16.

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GROWTH OF VARIOUS HYDRILLA RACES IN WATERS OF DIFFERING pH

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Abstract: *Fifteen races of hydrilla* [Hydrilla verticillata *(L.f.) Royle], collected throughout its geographical range, were grown for 5 weeks in natural water with the pH adjusted to 5, 7 or 9. Growth varied between as well as within races in response to individual pH. The largest growth increase occurred within the pH 7 treatment. A 700% difference occurred among races between the high and low ends of the response range. Growth response varied 5-fold between races at pH 5 and pH 9. Maximum growth of each race occurred at pH 7. Next best growth occurred at pH 5 with inhibition occurring in only 2 of 15 races. Reduced growth in 10 of 15 races at pH 9 may have been related to reduced free carbon dioxide supplies. Because growth was not completely inhibited is evidence that bicarbonate utilization mitigated the effects of limited availability of free carbon dioxide. Plants from the highly productive Queensland and Bangalore races exhibited a high tolerance for diverse pH. This indicates an ability to adapt, to colonize diverse habitats and to become more serious pests than races already established in the U.S.*

Hydrilla, a monotypic submersed aquatic weed in the monocot family Hydrocharitaceae, is widely distributed, having been reported from all continents except South America (Cook and Luond, 1982; Pieterse, 1981; Swarbrick et al., 1981). The dioecious pistillate plant was introduced in the U.S. around 1955 (Schmitz et al., 1990) and has become established predominantly in the warmer regions of the country. Monoecious plants recently discovered appear capable of growth in cooler regions (Steward et al., 1984; Steward and Van, 1987) and though not yet reported in the wild outside of the Northeastern states, are thriving in our cultures in South Florida.

The world-wide distribution of hydrilla is evidence of the ability of this species to tolerate diverse habitats, and the identification of numerous isoenzyme phenotypes among the several races of hydrilla collected world-wide is evidence of genetic variability (Ryan, 1989; Verkleij and Pieterse, 1986; Verkleij et al., 1983a; Verkleij et al., 1983b). Steward and Van (1987) observed that differences in physiological responses to photoperiod and temperature were greatest between races of different isoenzyme phenotypes but differences also occurred between races within isoenzyme phenotypes. This indicates that different physiological phenotypes occur within the species. Additional evidence was provided by van Vierssen and co-workers (1986) in earlier studies when they demonstrated that differences in leaf morphology existed between isoenzyme phenotypes. Morphology was altered between and within phenotypes by altering external concentrations of nitrate and bicarbonate. They concluded that leaf morphology was regulated both genetically and environmentally. The ability of submersed plants to grow in alkaline solutions indicates an ability to utilize bicarbonate for photosynthesis (Maberly, and Spence, 1983; Sand-Jensen and Gordon, 1986; Smith, 1985). This can provide competitive advantage when pH is high and carbon dioxide concentrations are low, such as during conditions of intense photosynthesis in dense plant stands. Bicarbonate utilization has been

TABLE 1. Approximate geographical location of the various collected races of hydrilla.

Race	Location		Flower[a]
Bangalore, India (BN)	13 N	77 E	S
Beijing, China (BJ)	40 N	116 E	PS
Chongqing, China (CQ)	29 N	106 E	P
Trapp Pond, DL (DL)	38 N	75 W	PS
Dyke Marsh, VA (DM)	38 N	77 W	PS
Florida (FL)	26 N	80 W	P
Guangzhou, China (GZ)	23 N	113 E	P
Kunming, China (KM)	25 N	102 E	PS
Lily Pons, MD (LP)	39 N	77 W	PS
New Guinea (NG)	6 S	144 E	PS
Lake Anne, NC (NC)	36 N	79 W	PS
Panang Island, Malaysia (PI)	5 S	100 E	PS
Cairn, Queensland, Aust. (QN)	17 S	145 E	PS
Taichung, Taiwan (TG)	24 N	120 E	PS
Tainan, Taiwan (TN)	23 N	120 E	PS

[a]Dioecious P = pistillate, S = staminate. PS = monoecious

demonstrated in dioecious hydrilla (Bowes, 1985; Steward, 1974; Van et al., 1976). It is possible that differences exist between hydrilla races since intraspecific variability in utilization of bicarbonate has been demonstrated in *Elodea canadensis*, another species of the Hydrocharitaceae (Sand-Jensen and Gordon, 1986).

Considering the reported plasticity in phenotypic expression of hydrilla, it is important that the biology of this plant be better understood in order to be prepared to cope with new introductions, should they occur. In this study, the effect of pH on growth responses of the several hydrilla races in the Agricultural Research Service collection at Ft. Lauderdale was evaluated to determine if there were differences in their ability to grow in environments of different pH and ultimately in their affinity for bicarbonate.

MATERIALS AND METHODS—The various races of hydrilla utilized in this study and the approximate geographical location of collection sites are given (Table 1). Stock cultures of the various races are being maintained in aquaria on the grounds of the research facility in Ft. Lauderdale.

Experiments were conducted outside in concrete aquaria 65 cm deep by 77 cm wide by 219 cm long placed under an open sided rain shelter covered with translucent fiberglass roofing panels. Individual aquaria were covered with 1 mm mesh grey fiberglass screening to prevent escape of plants and plant damage by snail-foraging birds. The roofing panels caused a 20% reduction in light and the fiberglass screening an additional 40% reduction for an average total reduction of 52%. Full sun at the dates of the study, 17 June to 23 July 1986, approximated 2200 μol.m^{-2}.s^{-1} light. A reduction of 52% of this value results in 1056 μol.m^{-2}.s^{-1} light or 176% of the light saturation value of the Florida race (Van et al., 1976). The photoperiod during the study ranged from 13.6 to 13.4 hours.

Hydrilla apical fragments 15 cm long from stock cultures were established, four per pot, in 15-cm diameter plastic pots containing 5% (v/v) composted cow manure in loamy sand. These pots were placed in 25 cm diameter pots to contain stoleniferous growth, and to prevent intermingling. The pots containing individual races were randomly placed in aquaria filled with natural pond water. The quality of this water, which has not changed, was previously described (Steward, 1984). Water temperature over the study period ranged from 25° to 27° C. After one week, water was drained from the aquaria and treatment water was transferred from adjacent aquaria in which the pH had been adjusted to 5, 7 or 9 with 2N HCl or NaOH. Measurements were taken with a portable research pH meter that was calibrated daily to pH 4.0 and pH 9.0 with buffer solutions. The pH of each treatment was adjusted daily with 0.1N acid or base. Treatment water adjusted to the correct pH was exchanged weekly. Treatments were replicated 4 times with aquaria as replicates and were arranged in a split-plot design with pH as main plots

TABLE 2. Pretreatment weight of individual hydrilla races after growth for one week in natural pond water of pH 7.5 ± 0.05.

Race	Oven dried weight grams[a]
Beijing, China (BJ)	0.60 a
Florida (FL)	0.50 ab
Lake Anne, NC (NC)	0.45 abc
Kunming, China (KM)	0.44 abcd
Panang Island, Malaysia (PI)	0.43 bcd
Bangalore, India (BN)	0.42 bcd
Chongqing, China (CQ)	0.41 bcd
Dyke Marsh, VA (DM)	0.39 bcde
Tainan, Taiwan (TN)	0.36 bcde
New Guinea (NG)	0.34 bcde
Taichung, Taiwan (TG)	0.32 bcde
Guangzhou, China (GZ)	0.31 cde
Cairn, Queensland, Aust. (QN)	0.27 cde
Lily Pons, MD (LP)	0.26 de
Trapp Pond, DL (DL)	0.22 e

[a] Mean weight of four replicates of four apical fragments per replicate. Means followed by a different letter are significantly different using Waller-Duncan Test KRATIO = 100.

and hydrilla races as subplots. All 15 races were represented in each replicate aquarium.

Plants were harvested after growth for 1 week in unadjusted pond water to obtain estimates of initial weight, and after growth for 5 weeks in pH-adjusted water. Measurement of the following parameters were used to obtain estimates of growth response to the pH treatments: (a) oven dry weight at 70° C (OD wt.) of non-reproductive tissues, (b) number and OD wt. of tubers and turions. Data analysis was accomplished using SAS ANOVA and GLM procedures for personal computers (SAS Institute Inc., Box 8000, Cary, NC 27511).

RESULTS—The initial or pretreatment weights of the various plant races, after growth for one week in pond water, differed approximately 3-fold from the lowest to the highest weights (Table 2). The mean and standard error of monthly pH readings of the water source, taken since 1975, has been 7.5 ± 0.05. The mean and standard error of the daily change in pH of the various treatments, calculated from the daily pH adjustments, were 0.50 ± 0.03, 0.26 ± 0.02 and −0.18 ± 0.01 for pH 5, 7 and 9.

The pH treatments produced differential growth responses among hydrilla races. The growth coefficient for the Delaware plants was 10 at pH 5, that is, a ten-fold increase in biomass over the pretreatment weight was produced in the pH 5 treatment (Table 3). This was significantly greater than the 7.3 growth coefficient of the New Guinea plants. The minimum significant difference between coefficients was 2.6 and as a consequence the races of plants segregated in broad groupings in this treatment. There were no differences among 11 other races, BN through BJ or NG through DM, which ranged from 7.3 to 4.6. At the high end of the range the grouping of growth coefficients was narrower, from 10 to 7.8 for the Delaware, Lily Pons, and Queensland plants. The plants of the Delaware race were more productive at pH 5 than 12 of 15 races.

Plants of the Delaware, Lily Pons, and Queensland races were again among the most productive when grown at pH 7 (Table 3). Their growth coefficients ranged from 11.9 to 10.8. The minimum significant difference between growth coefficients of races was 2.05 for this treatment. The races of plants segregated into a larger number of narrower groupings as a consequence. Calculation of optimum pH by regression analysis indicated the optimum to be near pH 7 for all races in which growth was affected by pH.

Growth of all races was reduced by the pH 9 treatment (Table 3). The highest growth coefficient was only 7.9 (QN) compared to 11.9 (LP) at pH 7 and 10 (DL) at pH 5. The Queensland race was again within the grouping at the high end of the range. The Bangalore and Guangzhou races, along with Queensland, exhibited the greatest tolerance for the pH 9 treatment. In this treatment, the ranking of the Lily Pons race decreased and moved nearer the middle of the range indicative of sensitivity to higher pH. Growth of the Delaware plants was also inhibited by the pH 9 treatment when compared with the Queensland race in this and previous treatments. Growth of the Guangzhou race was greater than the other races from China in the pH 9 and 7 treatments, evidence of physiological differences. The races collected in Taiwan responded similarly to pH treatments indicating the plants were of

TABLE 3. Response of hydrilla races[a] to pH 5, 7 or 9 after 5 weeks growth.

Ratio of Final:Initial Dry Weight[b]

pH5

DL	LP	QN	NG	BN	GZ	PI	TG	FL	CQ	TN	KM	NC	DM	BJ
10.0	9.0	7.8	7.3	6.9	6.8	6.7	6.2	6.0	5.9	5.7	4.9	4.9	4.7	4.6
a	a	a												
	b	b	b	b	b	b								
		c	c	c	c	c	c	c	c	c				
			d	d	d	d	d	d	d	d	d	d	d	
				e	e	e	e	e	e	e	e	e	e	e

pH 7

LP	DL	QN	GZ	BN	NG	FL	CQ	TG	BJ	DM	KM	TN	PI	NC
11.9	11.8	10.8	9.7	9.6	8.3	7.8	7.5	7.1	6.7	6.6	6.3	5.9	5.7	4.9
a	a	a												
		b	b	b										
			c	c	c	c								
					d	d	d	d	d	d	d			
						e	e	e	e	e	e	e		
							f	f	f	f	f	f	f	
									g	g	g	g	g	g

pH 9

QN	BN	GZ	DL	NG	FL	LP	CQ	PI	BJ	KM	TN	TG	NC	DM
7.9	7.3	6.7	6.4	6.0	5.8	5.6	5.3	4.6	4.3	4.3	4.0	3.8	3.3	3.2
a	a	a												
	b	b	b											
		c	c	c	c	c								
			d	d	d	d	d							
				e	e	e	e	e						
						f	f	f	f	f				
							g	g	g	g	g			
								h	h	h	h	h	h	
									i	i	i	i	i	i

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[a] See Table 1 for explanation of symbols.

[b] Means followed by a different letter are significantly different using Waller-Duncan test, KRATIO = 100.

the same physiological phenotype. The minimum significant difference between races in the pH 9 treatment was 1.32.

Ranking of growth coefficients averaged over pH for the races, in order of highest to lowest, was QN DL LP BN GZ NG FL CQ TG PI KM BJ TN DM NC. The Queensland, Delaware and Lily Pons races were consistently most productive while Tainan, Dyke Marsh and North Carolina were least productive. The coefficients of variation (CV: the standard deviation expressed as a percent of the treatment mean) can be used to compare the variability among races for the various treatments. The coefficients of variation of treatments were 26, 19 and 18.7 for pH 5, 7 and 9 respectively. Variability among the races was 40% greater within the pH 5 treatment than either of the other two treatments. The effect of this variability on statistical grouping of races was mentioned above.

Comparisons of growth responses of individual races to pH treatments reveal variable tolerance to extreme pH conditions (Table 4). Growth was not affected by pH in Bangalore, Florida, New Guinea, Panang Island, and Queensland races. Growth of the Beijing and Guangzhou races was reduced at pH 5 and growth of plants of 10 of the 15 races was reduced at pH 9. Growth of Panang Island plants, although not significantly affected by pH treatments, tended to increase with decreasing pH—a unique response within these collected races. The response patterns of the plants of the Delaware and Lily Pons races were not different from each other but were different from the Dyke Marsh race. The latter was speculated to have been distributed from the Lily Pons collection via Kennilworth Aquatic Gardens (Steward et al., 1984). These data indicate they may be physiologically different. There was no obvious response pattern associated with monoecious or dioecious plants (Table 1).

TABLE 4. Individual response to pH treatments of the various collected races of hydrilla.

Race	Ratio of Final:Initial Dry Weight[a]		
	pH 5	pH 7	pH 9
Bangalore, India (BN)	6.9 a	9.6 a	7.3 a
Beijing, China (BJ)	4.6 b	6.7 a	4.3 b
Chongqing, China (CQ)	5.9 ab	7.5a	5.3 b
Trapp Pond, DL (DL)	10.0 a	11.8 a	6.4 b
Dyke Marsh, VA (DM)	4.7 ab	6.6 a	3.2 b
Florida (FL)	6.0 a	7.8 a	5.8 a
Guangzhou, China (GZ)	6.8 b	9.7 a	6.7 b
Kunming, China (KM)	4.9 ab	6.3 a	4.3 b
Lily Pons, MD (LP)	9.0 a	11.9 a	5.6 b
New Guinea (NG)	7.3 a	8.3 a	6.0 a
Lake Anne, NC (NC)	4.9 a	4.7 a	3.3 b
Panang Island, Malaysia (PI)	6.7 a	5.7 a	4.6 a
Cairn, Queensland, Aust. (QN)	7.8 a	10.8 a	6.7 a
Taichung, Taiwan (TG)	6.2 a	7.1 a	3.8 b
Tainan, Taiwan (TN)	5.7 a	5.9 a	4.0 b

[a] Means within rows followed by a different letter are significantly different using Waller-Duncan test, KRATIO = 100.

Tuber production varied among races within pH treatments and tended to

TABLE 5. Effect of pH on tuber production among hydrilla races[a] after 5 weeks growth.

Tubers per pot[b]

pH5

BJ	TN	TG	KM	GZ	NG	CQ	DM	NC	QN	PI	LP	DL	FL	BN
7.0	4.3	4.0	4.0	3.5	3.3	3.0	2.0	1.0	1.0	0.5	0.5	0.0	0.0	0.0
a														
	b	b	b	b	b	b								
				c	c	c	c							
							d	d	d	d	d			
								e	e	e	e	e	e	e

pH 7

GZ	KM	CQ	DM	TN	TG	BJ	NG	LP	FL	BN	NC	QN	DL	PI
5.5	4.8	4.0	4.0	3.8	3.5	2.8	2.3	0.5	0.5	0.3	0.3	0.3	0.0	0.0
a	a	a	a	a	a									
	b	b	b	b	b	b								
		c	c	c	c	c								
						d	d	d	d					
							e	e	e	e	e	e	e	e

pH 9

KM	BJ	DM	GZ	TN	CQ	TG	NG	NC	PI	LP	BN	QN	DL	FL
7.8	7.5	7.3	7.3	5.8	5.0	4.8	2.3	0.5	0.3	0.3	0.3	0.3	0.0	0.0
a	a	a	a	a	a									
	b	b	b	b	b	b								
					c	c	c							
							d	d	d	d	d	d	d	d

[a] See Table 1 for explanation of symbols.

[b] Means followed by a different letter are significantly different using Waller-Duncan test, KRATIO = 100.

be higher at pH 5 and pH 9 than at pH 7 (Table 5). Tuber production was rapid in some races even though plants were exposed to non-tuber inducting photoperiods of 13 hours or more during the course of this study (Van et al., 1978). However since plants were propagated from stem apices, induction could have occurred as late as 1 May as short days extend from 9 September to 1 May at this latitude (26.05 N). Within races, tuber production was affected by pH treatment in only two races. The number of tubers produced by the Kunming race was highest at pH 9 and lowest at pH 7 for the Beijing race. Growth coefficients tended to be highest at pH 7 for all races and lowest at pH 9. Higher tuber production at pH 9 appears to be stress related since growth was generally retarded at this pH. This hypothesis is supported by the response data of Beijing plants whose growth was less at pH 5 and 9 than at pH 7 (Table 4) and Kunming plants whose growth was less at pH 9 than at pH 7. There were no differences in turion production.

DISCUSSION—Submersed aquatic plants, including hydrilla, depend on dissolved inorganic carbon (DIC) for photosynthesis (PS). Carbon dioxide is the preferred form for PS but its availability decreases rapidly with increasing pH due to kinetics of chemical equilibria in water (Stumm and Morgan, 1970). Approximately 96% of DIC is present as free CO_2 at pH 5, 21% at pH 7 and 0.3% at pH 9.

Availability of bicarbonate (HCO_3^-) has an inverse relationship to free CO_2, that is, 97% of DIC is present as HCO_3^- at pH 9, 79% at pH 7 and 3.8%

at pH 5. The photosynthetic rates of submersed plants which appear to only utilize CO_2 are strongly pH dependent. Rates of PS of these plants closely follow profiles of free CO_2 concentration in water and fall to zero at approximately pH 9 (Bain and Proctor 1980, Sand-Jensen 1987). The photosynthetic rates of aquatic plants which have been found to utilize HCO_3^- for PS continue beyond pH 9 but at reduced rates of approximately 10% of maximum under these alkaline conditions (Allen and Spence, 1981). The growth of hydrilla races in this study, although reduced, were still substantial at pH 9—evidence of bicarbonate utilization. Plants which utilize HCO_3^- increase the pH of the ambient medium to above 10 (Sand-Jensen, 1987) in the process of photosynthetic dehydration of bicarbonate i.e. $HCO_3^- \rightleftharpoons CO_2 + OH^-$ This is considered a criterion of bicarbonate utilization. Barko and co-workers (1988) observed pH maxima of 10 in dense stands of hydrilla in the Potomac River and diel variations in pH indicating a three-order of magnitude change in hydrogen ion activity. In 1989 growth chamber studies at this laboratory comparing tuber production of various hydrilla races, Steward observed that the pH of culture solutions (pond water) ranged from 8.8 to 10.4 after 48 hours growth (unpublished results).

In this study the reduced growth of 10 of 15 races of hydrilla at pH 9 can be tentatively attributed to reduced concentration of free CO_2. The factors responsible for the growth reduction of the Beijing and Guangzhou races at pH 5 were not obvious since free CO_2 would not be expected to be limiting at this pH. Spencer and Bowes (1985) subjected fifteen individual stem segments of Florida hydrilla per treatment to unreplicated treatments of pH 5, 7, and 9. They observed decreased growth of plants cultured in water adjusted to pH 5 and reported that growth was best at pH 7 and pH 9. Inspection of their data (mean ± standard deviations of % change/week) indicate that growth responses to treatments of pH 7 and pH 9 were greater than pH 5 treatments but not statistically different from each other. Their findings are at variance with this study since the Florida race did not respond differently to pH treatments. Although Spencer and Bowes offered no explanation for the difference in growth response to high and low pH, they concluded that hydrilla was more tolorant of pH than limnophila and hygrophila, the other two plants which were studied.

In this study, the growth response of hydrilla appears to be related to the indirect effects of pH on the CO_2/HCO_3^- equilibrium; however direct effects of pH on the growth of the plants cannot be ruled out. The nature of these direct effects are presently unknown.

The variable growth response to pH treatments of many of the different races of hydrilla is evidence that their affinity for carbon dioxide or bicarbonate utilization may differ. Total carbon concentration in treatment water did not vary in our studies; only the form in which carbon predominated, as determined by pH. The variable bicarbonate affinity observed by Sand-Jensen and Gordon (1986) in *E. canadensis* was a function of growth in habitats differing in DIC concentration. In order to further investigate carbon utilization in hydrilla, determinations of carbon dioxide and bicarbonate compensation points and affinities of the various races will need to be conducted in the laboratory in closed systems using methods similar to those of Allen and Spence (1981) and Sand-Jensen and Gordon (1986).

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LITERATURE CITED

ALLEN, E. D. AND D. H. N. SPENCE. 1981. The differential ability of aquatic plants to utilize the inorganic carbon supply in fresh waters. New Phytol. 87: 269-283.

BAIN, J. T. AND M. C. F. PROCTOR. 1980. The requirement of aquatic bryophytes for free CO_2 as an inorganic carbon source: Some experimental evidence. New Phytol. 86:393-400.

BARKO, J. W., G. L. GODSHALK, V. CARTER, AND N.B. RYBICKI. 1988. Effects of submersed aquatic macrophytes on physical and chemical properties of surrounding water. Tech. Report A-88-11, US Army Engineer Waterways Experiment Station, Vicksburg, MS. 28 p.

BOWES, G. 1985. Pathways of CO_2 fixation by aquatic organisms. p 187-210. *In:* Lucas W.J. and J.A. Berry (eds) Inorganic carbon uptake by aquatic photosynthetic organisms. Amer. Soc. Plant Physiol. Rockville, MD.

COOK, C. D. K. AND R. LUOND. 1982. A revision of the genus *Hydrilla* (Hydrocharitaceae). Aquat. Bot. 13:485-504.

MABERLY, S. C. AND D. H. N. SPENCE. 1983. Photosynthetic inorganic carbon use by freshwater plants. J. Ecol. 71: 705-724.

PIETERSE, A. H. 1981. *Hydrilla verticillata*—a review. Abstracts on Tropical Agriculture. Royal Trop. Inst., Amsterdam. 7:9-34.

RYAN, F.J. 1989. Isoenzymic variability in monoecious Hydrilla in the United States. J. Aquat. Plant Manage. 27:10-15.

SAND-JENSEN, K. 1987. Environmental control of bicarbonate use among freshwater and marine macrophytes. Pp. 99-112. *In:* CRAWFORD, R. M. M. (ed.) Plant life in aquatic and amphibious habitats. Spec. Publ. No. 5, Br. Ecol. Soc., Blackwell Sci. Publ., Oxford.

_________, AND D. M. GORDON. 1986. Variable affinity of *Elodea canadensis* Michaux in response to different HCO_3^- and CO_2 concentrations during growth. Oecologia.70:426-432.

SCHMITZ, D. C., B. V. NELSON, L. E. NALL, AND J. D. SCHARDT. 1990. Exotic aquatic plants in Florida: A historical perspective and review of the present aquatic plant regulation program. Proc. Symp. on exotic pest plants. Univ. Miami, Nov. 2-3, 1988. Miami, Fl (In Press).

SMITH, F. A. 1985. Historical perspective on HCO_3^- assimilation. Pp. 1-15. *In:* LUCAS, W. J. AND J. A. BERRY (eds.) Inorganic carbon uptake by aquatic photosynthetic organisms. Amer. Soc. Plant Physiol., Rockville, MD.

SPENCER, W. AND G. BOWES. 1985. Limnophila and Hygrophila: A review and physiological assessment of their weed potential in Florida. J. Aquat. Plant Manage. 23:7-16.

STEWARD, K. K. 1974. Growth of *Hydrilla* in solution culture at various nutrient levels. Quart. J. Florida Acad. Sci. 36:228-233.

_________. 1984. Growth of hydrilla *(Hydrilla verticillata)* in hydrosoils of different composition. Weed Sci. 32:371-375.

_________, T. K. VAN, C. CARTER, AND A. H. PIETERSE. 1984. *Hydrilla* invades Washington, D. C. and the Potomac. Amer. J. Bot. 71:162-163.

_________ AND T.K. VAN. 1987. Comparative Studies of Monoecious and Dioecious Hydrilla *(Hydrilla verticillata)* biotypes. Weed Sci. 35:204-210.

STUMM, W. AND J. J. MORGAN. 1970. Aquatic chemistry. An introduction emphasizing chemical equilibria in natural waters. Wiley-Interscience, N.Y.

SWARBRICK, J. T., C. M. FINLAYSON, AND A. J. CAULDWELL. 1981. The biology of Australian weeds. 7. *Hydrilla verticillata* (L.f.) Royle. J. Australian Inst. Agric. Sci. 183-190.

VAN, T. K., G. BOWES, AND W. T. HALLER. 1976. A comparison of the photosynthetic characteristics of three submersed aquatic plants. Plant Physiol. 58:761-768.

_________, W. T. HALLER, AND L. A. GARRARD. 1978. The effect of daylength and temperature on hydrilla growth and tuber production. J. Aquat. Plant Manage. 16:57-59.

VAN VIERSSEN, W., A. W. BREUKELAAR, AND H. W. PEPPELENBOS. 1986. A comparison of some morphological characteristics of four hydrilla strains under different environmental conditions. Proc. EWRS/AAB 7th Symp. on Aquatic Weeds. 369-374.

Verkleij, J. A. C. and A. H. Pieterse. 1986. Identification of *Hydrilla verticillata* (L.f.) Royle strains by means of isoenzyme patterns. Proc. EWRS/AAB 7th Symp. on Aquatic Weeds. 381-388.

________, A. H. Pieterse, G. J. T. Horneman, and M. Torenbeek. 1983a. A comparative study of the morphology and isoenzyme patterns of *Hydrilla verticillata* (L.f.) Royle. Aquat. Bot. 17:43-59.

________, A. H. Pieterse, H. P. M. Staphorst, and K. K. Steward. 1983b. Identification of two different genotypes of *Hydrilla verticillata* (L. F.) Royle in the USA by means of isoenzyme studies. Proc. International Symposium on Aquatic Macrophytes. Nijmegen, The Netherlands. 251-261.

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Biological Sciences

BURROW STRUCTURE AND PLACEMENT IN *GEOLYCOSA XERA* (ARANEAE: LYCOSIDAE)

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Abstract: *Burrow structure and placement of* Geolycosa xera *are reported for the first time. Significant positive correlations between burrow characteristics and body size were found. Burrows constructed in the field tended to be more highly correlated to body size than burrows constructed in the laboratory. Mean distance from the burrow to the nearest burrow was 95.4 cm.*

Species of *Geolycosa* are burrowing spiders that spend almost their entire existence in a burrow (Wallace, 1942). *Geolycosa domifex* (Hancock) uses burrows for protection against predation (McQueen, 1978) and *G. godeffroyi* uses them to reduce mortality resulting from climatic conditions (Humphreys, 1975). Burrow structure in *Geolycosa turricola* (Treat) and *G. pikei* (Marx) were recently described by Edwards and Edwards (1989). Miller and Miller (1984) reported correlations between burrow characteristics and body size in seven species of *Geolycosa.* I report here on the burrow structure and placement of *Geolycosa xera* McCrone, which constructs burrows in open sandy areas restricted to sandhill or sand pine scrub communities (McCrone, 1963).

Study Sites—Burrows were located in a sandhill community at Bok Tower Gardens, Lake Wales, FL (Polk county). The sandhill site was a xeric upland community dominated by longleaf pine (*Pinus palustris* Mill.), Turkey Oak (*Quercus laevis* Walt.), wiregrass (*Aristida stricata* Michx.), and saw palmetto (*Serenoa repens* (Bartr.) Small). Scattered within the site were sandy areas with sparse vegetation. It was within these sandy areas that *G. xera* constructed its burrows.

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METHODS—Burrows of *Geolycosa xera* were examined and measured from 9 August to 13 August, 1988. Burrows consisted of a turret of silk surrounding the burrow opening, radial silk threads extending out from the turret, and a long straight shaft with silk extending down from the turret 3-5 cm and opening into a cone-shaped chamber (Fig. 1-a).

The following measurements where performed on each burrow (n = 40) in the field: (1) distance of burrow to nearest vegetation, (2) distance to nearest burrow, (3) height of turret (from ground level), (4) widest diameter of burrow entrance, (5) depth of burrow, and (6) widest diameter of the cone-shaped chamber at the bottom of the burrow. Measurements 1-5 were performed before excavation of the burrow. Burrow depth was measured using a 0.25-cm diameter dowel. The dowel was placed in the burrow and allowed to rest on the bottom and then marked at surface level. The dowel was removed, measured, and then placed back into the burrow where it served as a guide for excavating the burrow. A large pit was carefully dug next to the burrow. Soil was slowly shaved away, moving towards the burrow, and allowed to fall into the pit. This procedure resulted in a cross-sectional view of the burrow. The diameter of the cone-shaped chamber at the bottom of the burrow was then measured. The spider was removed and returned alive to the laboratory. Field burrows were examined for prey remains.

In the laboratory the spiders were placed into 32 oz cups, and allowed to dig burrows. No burrows reached the bottom of the cup (depth of cups: 25 cm). All attempts to observe burrow construction failed.

Spiders were kept alive in the laboratory for at least 4 weeks before measuring their burrows, carapace width, and total body length. Field burrows and laboratory burrows were then compared. Measurements were taken only after no visible signs of digging had been seen for 2 weeks.

Carapace width and total body length of the excavated spiders were measured with an ocular micrometer. The Pearson correlation coefficient (SAS, 1985) was used to determine if correlations existed between burrow characteristic and body size.

Voucher specimens have been deposited at Florida State Collection of Arthropods, Division of Plant Industries, Gainesville, Florida.

RESULTS AND DISCUSSION—Mean distance from burrow to nearest plant was 10.5 cm (range: 0.5-52.5 cm, SE = 2.08). In all cases, a single, small weedy plant (grasses, sedges, herbs) was the closest type of vegetation. Mean distance from the burrow to the nearest burrow was 95.4 cm (range: 69.0-305.0 cm, SE = 11.56). Only two excavated burrows were vacant.

All burrows contained turrets and radial silk threads. Turrets averaged 0.7 cm in height (range: 0.2-1.8, SE = 0.08). Turret height increased as the spiders' total body length increased. Turrets were composed of sand grains fastened together with silk. Wallace (1942) postulated that the silk functioned in preventing cave-ins. Radial silk threads extended 3-6 cm out from the burrows, with the largest spiders having the longest radial silk threads. A number of spiders were observed sitting in their burrow entrance, apparently waiting for prey to trip the radial silk threads. Miller and Miller (1986) found that the average prey capture distance of *Geolycosa hubbeli* (Wallace) in Florida was less than 10 cm from their burrows.

TABLE 1. Pearson correlations for carapace width and total body length with burrow characteristics for *Geolycosa xera* in a sandhill community.

	Carapace width				Total Length			
	Burrow Depth	Widest Diameter of Entrance	Cone Shaped Chamber	Turret Height	Burrow Depth	Widest Diameter of Entrance	Cone Shaped Chamber	Turret Height
Laboratory	0.75*	0.06	−0.28	0.02	0.40	0.24	0.17	0.06
Field	0.85**	0.58**	0.04	−0.15	0.64**	0.39*	−0.29	−0.16

*P<0.01, **P<0.001

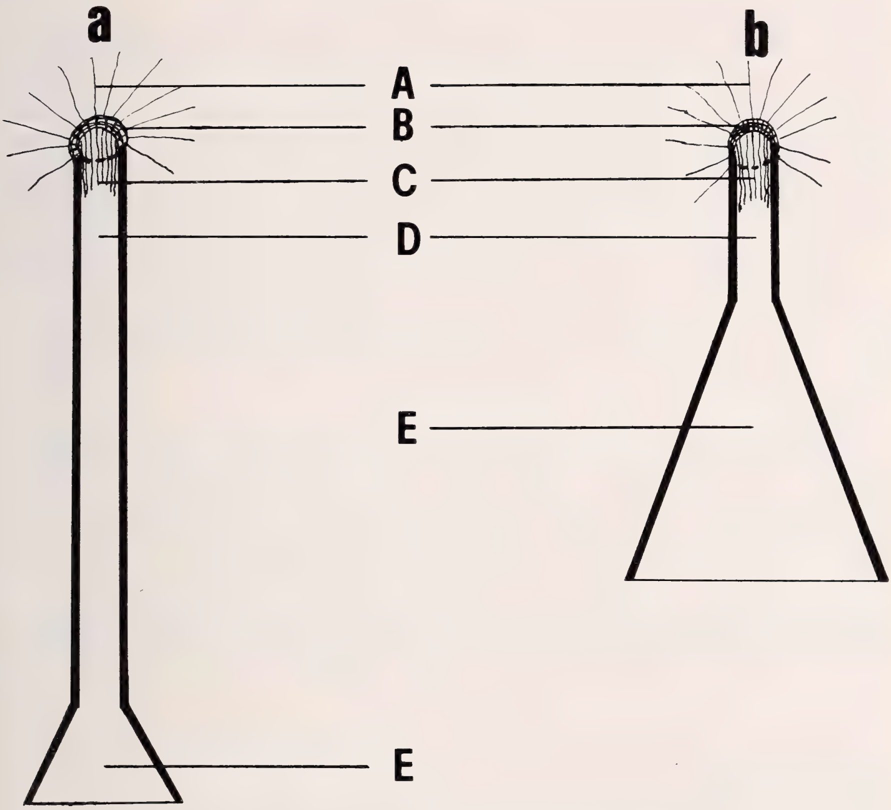

FIG. 1. Burrow structure of *Geolycosa xera:* l, field; r, laboratory. A = radial silk threads, B = turret, C = trip lines extending down into burrow, D = burrow shaft, and E = cone-shaped chamber.

The diameter of the burrow entrance and burrow depth were significantly correlated ($P<0.001$) with carapace width (Table 1). Miller and Miller (1984) found significant correlations between carapace width and burrow depth, and carapace width and widest diameter of the burrow entrance in all 7 species of *Geolycosa* they examined. Miller and Miller (1987) found that *Geolycosa* burrow diameters are just large enough to allow passage of one spider. For *Geolycosa domifex* (Hancock), the burrow diameter increased in size as the animal matured (McQueen, 1978). Significant correlations were also found between spider length and burrow depth and widest diameter of the burrow entrance. The burrows of *G. xera* differ from those of *G. pikei*, *G. turricola*, and *G. missouriensis* by having the shaft of the burrow open into a cone-shaped chamber at the bottom (Hancock, 1899; Edwards and Edwards, 1989; McCrone, 1963).

Only 28.9% of the spiders constructed burrows in the laboratory. The time from entering the cup to completion of the burrow varied from 1 to 14 days.

The height of turrets and diameter of burrow openings in laboratory burrows showed no measurable difference from field burrows. In all but two cases, laboratory burrows were shallower than field burrows. Burrows averaged 4.4 cm less in depth (range of depth differences: 1.0-10.4 cm) than those in the field. In the laboratory, only carapace width and burrow depth were significantly ($P<0.01$) correlated. Miller and Miller (1984) reported significant correlations between carapace width and burrow entrance in burrows constructed in the laboratory by *G. micanopy* Wallace and *G. patellonigra* Wallace.

Another notable difference between laboratory and field burrows was the diameter of the cone-shaped chamber and the point at which the chamber began below the surface (Fig. 1-b). All chambers in the laboratory were more than twice as wide as those found in the field ($\bar{x}$ difference: 2.1 cm, range: 1.7-2.7 cm).

The differences in burrow depths and chamber structure may be due to environmental conditions, such as a more constant temperature and humidity in the laboratory, or the burrow parameters may be a function of time.

No prey remains were found in field and laboratory burrows. Those spiders kept in the laboratory removed remains from the burrow.

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LITERATURE CITED

Edwards, R. L. and E. H. Edwards. 1989. Cape Cod's burrowing wolf spiders. The Cape Naturalist 18:12-19.

Hancock, J. L. 1899. The castle-building spider. Entom. News 10(2):23-29.

Humphreys, W. F. 1975. The influence of burrowing and thermoregulatory behavior on the water relations of *Geolycosa godeffroyi* (Araneae: Lycosidae) an Australian wolfspider. Oecologia 21:291-311.

McCrone, J. D. 1963. Taxonomic status and evolutionary history of the *Geolycosa pikei* complex in the Southeastern United States (Araneae, Lycosidae). American Midl. Nat. 70:47-73.

McQueen, D. J. 1978. Field studies of growth, reproduction, and mortality in the burrowing wolf spider *Geolycosa domifex* (Hancock). Canadian J. Zool. 56:2037-2049.

Miller, G. L. and P. R. Miller. 1984. Correlations of burrow characteristics and body size in burrowing wolf spiders (Araneae: Lycosidae). Florida Ent. 67:314-317.

Miller, G. L. and P. R. Miller. 1986. Pre-courtship cohabitation of mature male and penultimate female *Geolycosa turricola* (Araneae, Lycosidae). J. Arachnol. 14:133-134.

Miller, G. L. and P. R. Miller. 1987. Life cycle and courtship behavior of the burrowing wolf spider *Geolycosa turricola* (Treat) (Araneae, Lycosidae). J. Arachnol. 15:385-394.

SAS Institute. 1985. SAS User's Guide: Statistics. SAS Institute. Cary, North Carolina. 1290 pp.

Wallace, H. K. 1942. A revision of the burrowing spiders of the genus *Geolycosa* (Araneae, Lycosidae). Amer. Midl. Natur. 27(1):1-62.

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Biological Sciences

LABORATORY MEASUREMENT OF INGESTION RATE FOR THE SEA URCHIN *LYTECHINUS VARIEGATUS* (LAMARCK)(ECHINODERMATA: ECHINOIDEA)

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ABSTRACT: *Sea urchins* (Lytechinus variegatus) *from Biscayne Bay were fed controlled rations (5-cm blades) of turtle grass* (Thalassia testudinum) *every 48 hours over an 11-day period in 1988. The rations of grass consisted of either unblemished (green) blades or decayed blades. Decayed blades had nearly twice as much dry weight as green blades of the same size. Ingestion times for both types of turtle grass were negatively correlated with sea urchin size (bigger urchins ate faster than smaller urchins). Mean ingestion times for the two types of blades were significantly different (decayed blades < green blades). Sea urchins did not show a preference when offered a green and decayed blade at the same time.*

MOORE and co-workers (1963), Oliver (1987), and Montague and co-workers (1988) reported field data that suggest the sea urchin *Lytechinus variegatus* (Lamarck) is a common grazer of turtle grass *(Thalassia testudinum)* in the subtidal seagrass meadows of Biscayne Bay. Little is known, however, about this species' impact on turtle grass standing crop or productivity. Here we report laboratory estimates of the rates at which individual sea urchins ingested 5-cm blades of green and decayed turtle grass. The results may provide new insight into the ecological impact of these grazers on turtle grass community dynamics.

METHODS—Turtle grass was collected from the Bear Cut Channel along the northern shore of Key Biscayne (25°46′N: 80°10′W). Blades of turtle grass were cut to 5-cm lengths (after Hay, 1984). Green, unblemished turtle grass blades were cut from the base of the leaf. The decayed blades were cut from the distal portions of the leaf. Blades of both types were approximately 1 cm in width. Samples of turtle grass (30 5-cm blades of each type) were dried at 60°C for 48 hr., and dry weights were recorded.

A sample of 20 sea urchins was collected from the Bear Cut Channel in September, 1988. The diameter of each urchin was recorded. The urchins were kept in 20-gallon marine aquaria (five per tank) at approximately 25°C. They were starved for 48 hours before the feeding tests began (after Lowe and Lawrence, 1976). At the start of the feeding tests each urchin was offered a 5-cm blade of turtle grass. Ten urchins received only green blades, 10 received only decayed blades. We recorded: (1) the time the urchin's tube feet made contact with the blade, (2) the time the blade came in contact with the teeth, and (3) the time when the urchin either completely ingested the blade, or, stopped eating (the urchin moved the blade onto its aboral surface). This procedure was repeated every 48 hours for 11 days. Ingestion time was measured as the period after the blade first made contact with the teeth to the time the urchin had finished the blade (or moved the uneaten portion to its aboral surface).

We calculated: (1) mean ingestion time for each urchin (over 11 days), and (2) mean ingestion time for each day. The ingestion times were used in a two-way ANOVA (blade type by days). The individual ingestion times were first transformed with a natural logarithmic function to ensure homogeneity of variances (see Sokal and Rohlf, 1987, p. 218). Pearson's correlation coefficients (r) were estimated for urchin size vs. ingestion time. These values were calculated for both non-transformed and transformed (natural log) ingestion times.

A second sample of 10 urchins was collected in July 1988. These were used to test blade preferences. Each urchin was offered (simultaneously) a green and decayed blade (side-by-side). We recorded which blade arrived first at the teeth. This procedure was repeated every 48 hours for the next four days. The final three observations were made five days apart. A total of 50 choices were observed. We calculated P as the number of green blades chosen first divided by the total number of choices. Assuming the urchins had no preference, we tested the hypothesis that the urchins would choose the blades in equal proportions (H_0: $P = 0.50$). We then used chi-square analysis to compare observed choices with predicted choices.

Table 1. Mean ingestion time (in hours) for 5-cm blades of green and decayed turtle grass (10 urchins per cell). Value in parenthesis = one standard deviation.

Date	Green Blades	Decayed Blades
9/21/88	3.35 (0.79)	2.36 (0.47)
9/23/88	2.84 (0.73)	2.22 (1.16)
9/25/88	2.41 (0.52)	2.20 (0.95)
9/27/88	2.79 (0.95)	2.19 (0.03)
9/29/88	2.99 (0.62)	2.67 (1.18)
10/1/88	2.59 (0.62)	2.38 (0.64)
Over-all	2.83 (0.79)	2.34 (0.92)

Results—The mean dry weight of the 30 green blades was 39.0 mg (one standard deviation = 25.1), and the mean dry weight of the 30 decayed blades was 71.0 mg (one standard deviation = 36.9).

The mean ingestion times (in hours) for the two blade types are shown in Table 1. Urchins ingested the blades at signifi-cantly different rates (decayed < green). We did not calculate ingestion rate relative to urchin weight (grams ingested/urchin weight) because we had no reliable method to convert urchin diameter to biomass. Moore and co-workers (1963) reported regression data for the conversion of diameter to volume, but not for diameter to weight. During the feeding tests, some portions of blades were uneaten; eight of the ten urchins did not eat all of the green blade at least once, and two of the 10 urchins did not eat all of the decayed blade at least once.

Table 2. Two-way ANOVA (turtle grass type by days) for mean ingestion time. All eating times first transformed with the natural logarithmic function (cf. Sokal and Rohlf 1987, p. 218).

Source	Sum of Squares	d.f	Mean Square	F Ratio	Prob.
Blade type	0.925	1	10.925	8.85	<0.01
Days	0.473	4	0.118	1.13	0.35
Interaction	0.146	4	0.037	0.35	0.84
Within	9.410	90	0.105		
Total	10.954	99			

The two-way ANOVA (Table 2) showed that the mean ingestion time for decayed turtle grass was less than mean ingestion time for green turtle grass ($p<0.01$). There were no significant effects due to either days of observation ($p=0.35$) or interaction between blade type and days ($p=0.84$).

Urchin size was negatively correlated with both non-transformed and transformed ingestion times, for both green and decayed blades (Table 3, and Figure 1).

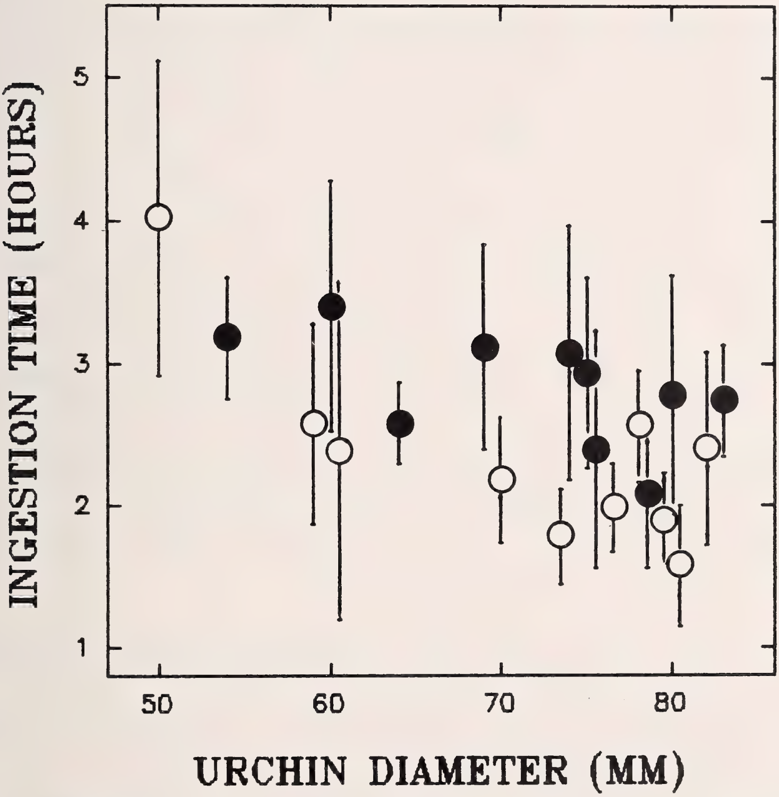

FIG. 1. Urchin size (mm) vs. ingestion time (hours) for the two blade types. The circles are mean times, and the vertical bars are ± one standard deviation. The closed circles represent mean ingestion times for green turtle grass, and the open circles represent mean ingestion times for decayed turtle grass.

TABLE 3. Correlation coefficients for urchin size vs. ingestion time. Values in parentheses are based on ingestion times transformed with the natural logarithmic function (cf. Sokal and Rohlf 1987, p. 218).

Blade Type	Correlation Coefficient	Degrees of Freedom	Prob.
Green	−0.34	48	0.03
n = 10 urchins	(−0.35)	(48)	(0.02)
Decayed	−0.57	48	<0.001
n = 10 urchins	(−0.51)	(48)	(<0.001)

The 10 urchins of the second sample showed no significant preference for either green or decayed blades ($P = 0.42$; $X^2 = 1.28$; prob. $= 0.31$).

Discussion—*L. variegatus* is a generalist grazer in the turtle grass meadows of South Florida. It is primarily herbivorous and feeds extensively on turtle grass. McClintock and co-workers (1982) noted that these urchins also consume animal protein when available. They have very poor ability to detect food items at a distance (Klinger and Lawrence, 1985). Their discrimination of individual food items seems to be more closely attuned to physical rather than chemical cues (Klinger and Lawrence, 1984). This might explain why our second sample of test urchins showed no significant preference for either blade type. It is arguable whether our procedure represented a sufficiently discriminating technique for ascertaining preference, but it did provide preli-minary data for the design of new preference studies.

Our study focused on ingestion of discrete items (5-cm blades of turtle grass). We recognize, however, that sea urchins might graze sporadically on discrete items in the field. Our lab results should be viewed in this cautious light. Some field estimates of ingestion rate are available (Moore et al, 1963; Hay, 1984). Moore and co-workers (1963) estimated that a *L. variegatus* urchin with a diameter of 63 mm would consume an average of 272 mg (dry) of turtle grass per day. This estimate was based upon both field and laboratory tests, though specific temperatures were not noted. Moore and McPherson (1965) suggested that ingestion rates for *L. variegatus* are (more or less) constant over seasons. Extrapolation of our data (Figure 1) indicates the ingestion of 272 mg (dry) of turtle grass by a 63-mm urchin would require roughly 8-10 hours per day at 25°C. Thus, *L. variegatus* in the field might spend 30-40% of its total time eating turtle grass.

Previous workers (Klinger, 1982, 1984; Klinger et al., 1986, and Klinger et al., 1988) estimated laboratory ingestion rates for *L. variegatus*. They measured consumption of controlled food rations (various mixtures of dried turtle grass extracts and agar). Lowe and Lawrence (1976) analyzed the nutritional qualities and absorption efficiencies of turtle grass in comparison with other marine vegetation. It is difficult, however, to compare these laboratory results to ours.

We found a negative correlation between urchin size and ingestion rate, i.e., bigger urchins tended to eat faster than smaller urchins. Klinger (1982) noted a similar effect in his lab study. If this tendency holds for field populations, then both density and size distribution of urchins may have critical effects on grazing intensity. Oliver (1987) reported seasonal variation in the densities and size distributions for the Bear Cut urchins. Thus, the over-all grazing intensity on turtle grass probably shows significant variation during the year.

The difference in rates at which the urchins ingested the blades suggest that green, unblemished turtle grass may not be a particularly palatable food compared with decayed turtle grass. If so, urchins in the field may find it more profitable to selectively graze on decayed portions of the leaves. The experiments of McClintock and co-workers (1982) also suggest that these decayed portions might be grazed preferentially by urchins in the field. It is unknown whether urchins might discriminate between green and decayed leaf portions in the field. Such discrimination might be based upon physical cues, or, instead, upon nutritional qualities. More detailed field analyses of urchin grazing (cf. Lowe and Lawrence, 1976) are needed to address this question.

Population densities of the urchins may be regulated by the productivity of turtle grass. Alternatively, urchin densities may be regulated by factors independent of productivity (e.g., by UV-damage or predation: Oliver, 1987). Recent measurements on turtle grass productivity are available (Jensen and Gibson, 1986), but little is known of the impact of urchin grazing on this productivity. If urchins in the field graze preferentially on decayed turtle grass, then the total standing crop of turtle grass at any one time might be an over-estimate of the food actually available to the urchins. The hypothetical carrying capacity (K) for urchins at any one time might be more realistically viewed by first partitioning the total standing crop of turtle grass into green and decayed fractions. Such partitioning ought to be examined over time to detect seasonal variation. We see a clear need for accurate assessment of turtle grass tissues *in situ*, and more field research on grazing behavior.

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LITERATURE CITED

HAY, M.E. 1984. Patterns of fish and urchin grazing on Caribbean coral reefs: are previous results typical? Ecology 65(2):446-454.

JENSEN, P.R. AND R.A. GIBSON. 1986. Primary production in three subtropical seagrass communities: a comparison of four autotrophic components. Florida Scient. 49(3):129-141.

KLINGER, T.S. 1982. Feeding rates of *Lytechinus variegatus* Lamarck (Echinodermata: Echinoidea) on the differing physiognomies of an artificial food of uniform composition. Pp. 29-33. *In* Echinoderms: Proceedings of the International Echinoderms Conference, LAWRENCE, J. M., (ed.) A. A. Balkema, Rotterdam, the Netherlands.

———— 1984. Feeding of a marine generalist grazer: *Lytechinus variegatus* (Lamarck) (Echinodermata: Echinoidea). 216 p. Ph.D. dissert., Univ. of South Florida, Tampa, Florida.

———— AND J.M. LAWRENCE. 1984. Phagostimulation of *Lytechinus variegatus* (Lamarck) (Echinodermata: Echinoidea). Mar. Behav. Physiol. 11:49-67.

———— AND J.M. LAWRENCE. 1985. Distance perception of food and the effect of food quantity on feeding behavior of *Lytechinus variegatus* (Lamarck) (Echinodermata: Echinoidea). Mar. Behav. Physiol. 11:327-344.

————, H. L. HSIEH, R. A. PANGALLO, C. P. CHEN, AND J. M. LAWRENCE. 1986. The effect of temperature on feeding, digestion, and absorption of *Lytechinus variegatus* (Lamarck) (Echinodermata: Echinoidea). Physiol. Zool. 59(3):332-336.

————, S. A. WATTS, AND D. FORCUCCI. 1988. Effect of short-term feeding and starvation on storage and synthetic capacities of gut tissues of *Lytechinus variegatus* (Lamarck) (Echinodermata: Echinoidea). J. Exp. Mar. Biol. Ecol. 117:187-195.

LOWE, E. F. AND J. M. LAWRENCE. 1976. Absorption efficiencies of *Lytechinus variegatus* (Lamarck) (echinodermata: Echinoidea) for selected marine plants. J. Exp. Mar. Biol. Ecol. 21:223-234.

McClintock, J. B., T. S. Klinger, and J. M. Lawrence. 1982. Feeding preferences of echinoids for plant and animal food models. Bull. Mar. Sci. 32(1):365-369.

Montague, J. R., L. Ortiz, A. Arguelles, J. M. Millan, and L. Cardoch. 1988. Density and dispersion estimates for sea urchins in a South Florida seagrass community. Florida Scient. 51(1):19-22.

Moore, H. and B. McPherson. 1965. A contribution to the study of productivity of sea urchins *Tripneustus esculentus* and *Lytechinus variegatus*. Bull. Mar. Sci. 15:855-871.

———, T. Jutare, J. C. Bauer, and J. A. Jones. 1963. The biology of *Lytechinus variegatus*. Bull. Mar. Sci. Gulf Carib. 13(1):23-53.

Oliver, G. D. 1987. Population dynamics of *Lytechinus variegatus*. 104 p. M.S. thesis, University of Miami, Coral Gables, Florida.

Sokal, R. R. and F. J. Rohlf. 1987. Introduction to Biostatisitics (2nd Ed.). 363 p. W.H. Freeman and Company, San Francisco.

Florida Scient. 54(3/4): 129-134. 1991.
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FROM THE EDITORS:

From time to time in response to complaints, we say, “We may run the train, but we don’t own the railroad.” This is the first time we have said it in print. We may have the honor and the responsibilities of being editors, but others in the Florida Academy of Sciences make decisions that affect us.

Members of the FAS Council decide how many pages will be published in a year. The Council is composed of the officers and others listed on the masthead, as well as the Chairs and Chairs-Elect of the Sections of the Academy, Membership-at-large, and Chairs of important standing committees.

The editors are not responsible for distribution or billing. Those are the responsibilities of the Executive Secretary.

For the past five years, Dr. Alex Dickison has served in that important office, and Mrs. Christine Murphy Hamilton served as his secretary. We will miss working with both of them, and we and others are grateful for their dedicated service.

We look forward to working with Mrs. Betty Preece, who recently accepted a five-year appointment as FAS Executive Secretary. Her address and telephone number are listed elsewhere. We wish her the best of luck and all good fortune in her new responsibilities.

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COMPETITIVE INTERACTION BETWEEN MONOECIOUS HYDRILLA AND AMERICAN EELGRASS ON SEDIMENTS OF VARYING FERTILITY

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Abstract: *Monoecious hydrilla* [Hydrilla verticillata *(L.f.) Royle] from the Potomac River and American eelgrass* (Vallisneria americana *Michx.) were grown in monoculture and in mixed culture on aquatic sediments of decreasing fertility to assess their ability to compete for nutrients. Biomass yield in hydrilla decreased with decreasing fertility and increased an average of 45% when grown intermixed with eelgrass. This was interpreted as evidence of within species competition. Biomass yield only decreased in eelgrass when grown on sand, evidence of lower nutrient requirements than hydrilla. Sediment fertility had little effect on nutrient concentrations in tissues, except that concentrations were depressed when plants were grown on sand alone. Reduced growth of hydrilla was not related to tissue concentrations of measured nutrients. Nutrient accumulation in plant tissues was most closely related to dry weight and was greatest in hydrilla. Potassium accumulation in plant tissues exceeded supplies in sediments indicating potassium uptake occurred from ambient water. Sediment potassium concentrations were increased by plant growth in some sediment treatments.*

The discovery of 12 submersed species in a 1983 survey signalled the return of aquatic vegetation to the Potomac River after an absence of over half a century (Haramis and Carter, 1983; Rybicki and Carter, 1986). In 1982, prior to the observed reappearance of native species, a monoecious variety of the exotic species hydrilla was discovered growing in an embayment of Dyke Marsh on the Virginia side of the river south of Alexandria (Steward et al., 1984). Since its discovery, colonies of hydrilla have become established on both sides of the river upstream from Dyke Marsh and 37 km downstream (Rybicki et al., 1987). Rybicki and Carter (1987) reported that hydrilla was dominating approximately 95% of the vegetated areas of the upper tidal river.

The spread of hydrilla is impacting the re-establishment of native submersed species as well as the adventive species, Eurasian watermilfoil (*Myriophyllum spicatum* L.). The displacement of one species by another can be through competition for limited resources or through inhibition by allelopathic substances (Frank and Dechoretz, 1980; Harper, 1977; Rice, 1974; Yeo and Thurston, 1984). There is no evidence that hydrilla produces allelochemicals. The dependence of rooted aquatic macrophytes on sediments as a resource for nutrients is well documented (Barko and Smart, 1980; Steward, 1984). Evidence suggests that phosphorus and nitrogen are supplied to these plants predominantly from sediments and as a consequence have potential for becoming growth limiting (Carignan and Kalff, 1980; Chen and Barko, 1988). Current knowledge of the nutritional physiology of dioecious hydrilla indicates that roots are functional in utilizing nutrients from bottom substrates (Barko and Smart, 1983, 1986; Steward, 1984). Monoecious hydrilla appears to possess many of the same growth characteristics as the dioecious type, but little documented information is available to evaluate its competitive nature. This study was undertaken to assess the interaction of monoecious hydrilla and American eelgrass when competing for nutrients by conducting limited replacement series (Harper, 1977) experiments on sediments of varying fertility. A secondary objective of this investigation was to determine the effects of plant growth on the nutrient contents of sediments supporting this growth.

METHODS AND MATERIALS—*Plant Materials*—Eelgrass was collected from wild colonies in a pond adjacent to the laboratory in Davie, FL. Monoecious hydrilla, originally collected from Dyke Marsh on the Potomac River in Virginia, was obtained from cultures maintained at the laboratory. Apical stem sections, 10 cm long, of hydrilla and 5 cm long eelgrass plants were placed in sand in aquaria where they remained for one week prior to transfer to the experimental sediments. At the time of transfer twenty plants of each species were subsampled for estimates of fresh and oven (65 C) dry weight.

Experimental Sediments—Sediments were prepared by mixing sediment collected from the North New River (NNR) Canal in Davie, FL with commercial builders sand. These sediments, which have long supported vigorous stands of dioecious hydrilla, were collected with a core sampler (Sutton, 1982). Sample aliquots were spread over kraft paper in a screen house to air dry, sieved through 6 mm galvanized screen when dry and then thoroughly mixed. Sediments were diluted with dry sand on a volume:volume basis to provide sediment treatments of decreasing fertility which consisted of 100 (S1), 75 (S2), 50 (S3), 25 (S4), and 0% (S5) sediment. The mean values of triplicate weight measurements of each component of each volume mix were used to determine the proportion of each component in the mix. Thereafter the mixtures were prepared by weight to reduce variability resulting from uneven settling of substrate. A total of 264 cc of sediment mixture was placed in each 10-cm diameter pot which was lined with a polyethylene bag.

Reference Sediments—Sediments from three locations in the Potomac River were collected 7 May 1987 to obtain estimates of fertility for comparison with NNR sediments. Sediments were collected with a core sampler, as described above, at three locations: 1) at the base of the bridge support on the East end of Woodrow Wilson Memorial Bridge, 2) in Hunting Bay near Alexandria, VA and 3) in Dyke Marsh, 3 miles South of Alexandria adjacent to George Washington Memorial Parkway. Collected sediments were placed in large polyethylene bags until spread out to dry in Florida, approximately 24 h later. Samples were processed as described above.

Experimental Design—This study was conducted as a substitutive experiment (replacement series), where total plant density was constant and the species proportion varied. The premise of the replacement series experiment is to determine yields of mixtures by comparison to monoculture yields (Harper, 1977). Plants were present at three densities: a) two hydrilla, b) two eelgrass and c) one of each species combined. Sediments were present in five proportions as indicated above. Treatments were arranged as a split-plot with plants as the main plot component and sediments as subplots. Treatments were replicated 4 times with individual 1000 L capacity concrete aquaria constituting one replicate. Each aquarium contained plants in five pots representing the five proportions of sediments. Aquaria and pots within aquaria were randomized.

A second experiment was conducted to assess effects of plant growth on nutrient contents of the sediments supporting this growth. This experiment was arranged as a split-plot design with five main plot levels of sediment nutrients as follows: initial level (sediment not subjected to treatment), control level (sediments subjected to experimental conditions without plants to determine leaching losses) and sediments planted to the three plant combinations. Subplots were the five sediment proportions, described above, in each of four aquaria. This second experiment was accomplished simply by including an additional 4 aquaria containing five pots of sediment mixtures without plants and was conducted simultaneously with the other experiment. The density of two plants per container was below the carrying capacity of containers which was determined to be 8-10 plants (27 g dry wt) for hydrilla and 6-8 plants (9 g dry wt) for eelgrass.

Individual aquaria were covered with gray fiberglass screen covers to prevent bird damage. The covers reduced ambient light by 40%. Continuous water flow through the aquaria provided a complete volume change in 12 hours. Source and quality of the water supply was reported earlier (Steward, 1984) and has not changed. The experiment was started 10 August 1987 and ended 22 September 1987 after 43 days.

Sample preparation—At harvest the plants were separated from wet sediments, washed in a stream of the same water in which they were grown, separated into shoots and roots, dried for one week at 65°C and weighed. Stolons, when present, were included with shoots. Weighed tissues were ground to pass a 40 mesh screen and stored in a desiccator until analyzed. Saturated sediment was transferred from pots to plastic bags immediately after plants were harvested. The pH of the saturated sediment samples was determined with a glass electrode by pH meter (Peech, 1965), after which 10 ml thymol-saturated water was mixed with sediment samples to stop biological activity and samples were stored at 4°C. Analyses were completed by four weeks after collection.

Tissue Analyses—Quantities of the macronutrients phosphorus, nitrogen, calcium, magnesium, and potassium were estimated from samples digested in a sulfuric acid-peroxide solution by a modified method of Allen and workers (1974), (two selenized Hengar granules replaced selenium). Quantities of the micronutrients-copper, manganese, iron, and zinc-were estimated in samples digested with nitric acid-hydrogen peroxide solution. The metal concentrations were quantitatively determined by atomic absorption spectrometry. Phosphorus content was determined colorimetrically as orthophosphate-P by the ascorbic acid method (APHA, 1985). Nitrogen was determined as ammonia-N by the spectrophotometric nesslerization method (APHA, 1985). Tomato leaves (National Bureau of Standards) were used as a reference standard. Analyses of the acid digest of NBS tomato leaves resulted in 95% or better recovery of N, K, Mg, P, and Ca.

Sediment Analyses—Available nutrient contents were estimated in sediment samples after extraction with Mehlich No. 1 reagent (0.05 N HCl in 0.025 N H_2SO_4 mixture) for sandy soils (Jones, 1980), or digested with concentrated sulfuric acid-hydrogen peroxide solution (27.8 N H_2SO_4 + 30% H_2O_2 mixture) by the same procedure used for plant tissues (Allen et al., 1974). The nutrients, P, Ca, Mg, and K were measured by the procedures described above. River sediment (National Bureau of Standards) was used as a reference to determine reliability and accuracy of the extraction procedures. Recovery of Cu, Mn, and Zn was 95% and Fe was 74%. Sediment texture analyses were performed using the hydrometer method of particle size analysis (Black, 1965; Cox, 1967). Sediment textural classes were categorized using standard soil texture triangle diagrams (Millar, Turk, and Foth, 1958).

Statistical analyses were performed using SAS ANOVA and GLM procedures for personal computers (SAS Institute Inc., Box 8000, Cary, NC 27511).

RESULTS AND DISCUSSION—*Aquatic Sediments*—Results from analyses of sulfuric acid-hydrogen peroxide extracts for available nutrient contents of river sediments are shown (Table 1). The Potomac River sediments were gen-

TABLE 1. Comparison of total soil nutrients in North New River (NNR) Canal and Potomac River sediments.

Element	NNR	DM	HB	WB
Nitrogen	3,900 ± 22 c[2]	16,800 ± 400 a	14,200 ± 900 b	12,800 ± 1,400 b
Phosphorus	424 ± 29 c	3,700 ± 101 a	900 ± 400 b	980 ± 20 b
Calcium	35,200 ± 2,840 b	8,500 ± 100 d	47,300 ± 400 a	18,400 ± 2,600 c
Magnesium	2,310 ± 63 c	4,700 ± 40 b	5,700 ± 80 a	4,800 ± 70 b
Potassium	460 ± 9 d	11,600 ± 70 a	10,800 ± 60 b	9,600 ± 40 c
Manganese	81 ± 13 d	792 ± 24 b	1,064 ± 10 a	726 ± 12 c
Zinc	47 ± 4 d	3,700 ± 284 a	2,626 ± 52 b	1,948 ± 35 c
Iron	9,700 ± 134 d	45,600 ± 100 a	44,000 ± 300 b	38,600 ± 200 c
Copper	52 ± 1 b	76 ± 1 a	50 ± 1 b	49 ± 2 b
Soil Texture:	Sandy Loam 2% Clay 26% Silt 72% Sand	Silt Loam 6% Clay 54% Silt 40% Sand	Silt Loam 6% Clay 53% Silt 41% Sand	Sandy Loam 6% Clay 47% Silt 47% Sand

[1] DM: Dyke Marsh; HB: Hunting Bay; WB: Wilson Bridge

[2] Mean mg/kg ± standard errors of 5 samples. Means within rows followed by same letter not different using Waller-Duncan Test, K ratio = 100.

erally more highly fertile than the Florida sediment. The exceptions were calcium concentration in the Dyke Marsh and Wilson Bridge sediments and copper concentration in the Hunting Bay and Wilson Bridge sediments. The high nutrient concentrations in the Potomac River sediment may be due in part to treated effluent from the Blue Plains municipal treatment plant which is discharged upstream of Wilson Bridge on the Maryland side of the river. Nutrient element concentrations of the Potomac River sediments were generally highest in Dyke Marsh sediment, lowest in Wilson Bridge sediment, and intermediate in Hunting Bay sediment. The lowered silt content of Wilson Bridge sediment suggests a scouring influence of water current on soil texture.

Growth Response—Hydrilla dry matter production (total weight) was greater (sediment treatments S1, S2 and S4) when grown in mixed culture with eelgrass than when grown in monoculture (Table 2). Shoot dry weight increased an average of 45% when grown in mixed culture. Growth of eelgrass was not affected when grown in mixed culture with hydrilla. Growth of eelgrass, in monoculture or in mixed culture, was not affected by sediment treatments, except when grown in sand alone. Root weight was greatest in eelgrass. Sediment treatment had no effect on root growth, nor did growing plants in mixed culture. Shoot:root ratios in eelgrass were less than in hydrilla

Table 2. Comparison of growth for hydrilla and eelgrass grown in monoculture or in mixed cultures (c) in five levels of soil fertility. Data adjusted to reflect growth of single plant.[1,2]

	S1[3] (1:0)	S2 (3:1)	S3 (1:1)	S4 (1:3)	S5 (0:1)	ME[4]-Plant
			TOTAL DRY WEIGHT (g)			
Hydrilla	5.4Ba	5.1Ba	2.8ABb	2.1Bbc	0.3Nc	3.1B
Eelgrass	1.1Ca	1.0Ca	1.1Ba	0.7Cab	0.2Nb	0.8C
Hydrilla(c)	8.6Aa	7.2Aa	3.2Ab	3.7Ab	0.4Nc	4.6A
Eelgrass(c)	1.1Cab	0.4Cb	1.9ABa	1.1Cab	0.2Nb	0.9C
ME[4]-Soil	4.0a	3.4a	2.3b	1.9b	0.3c	
			SHOOT DRY WEIGHT (g)			
Hydrilla	5.2Ba	5.0Ba	2.7ABb	2.0Bbc	0.3ABc	3.0B
Eelgrass	1.0Ca	0.9Ca	1.0Ca	0.6Cab	0.1Bb	0.7C
Hydrilla(c)	8.3Aa	7.0Aa	3.1Ab	3.6Ab	0.4Ac	4.5A
Eelgrass(c)	0.9Cab	0.3Cb	1.5BCa	0.9Cab	0.2ABb	0.3C
ME-Soil	3.9a	3.3a	2.1b	1.8b	0.2c	
			ROOT DRY WEIGHT (g)			
Hydrilla	0.05Bn	0.06Bn	0.04An	0.03Bn	0.02Nn	0.04C
Eelgrass	0.14ABn	0.14An	0.13An	0.13ABn	0.04Nn	0.12AB
Hydrilla(c)	0.08ABa	0.08ABa	0.04Aab	0.06Bab	0.02Nb	0.05BC
Eelgrass(c)	0.16Aa	0.07ABa	0.40Aa	0.17Aa	0.39Na	0.17A
ME-Soil	0.11ab	0.08ab	0.15a	0.10ab	0.03b	
			SHOOT:ROOT RATIO			
Hydrilla	125Aa	130Aa	83Aab	61Aab	13Bb	82A
Eelgrass	6Bab	7Aa	7Ba	6Bab	3Bb	6B
Hydrilla(c)	128An	127An	89An	74An	28An	89A
Eelgrass(c)	6Bn	4An	5Bn	6Bn	5Bn	5B
ME-Soil	66a	67a	46a	37ab	12b	

[1] Column means followed by same upper case letter not different using Waller-Duncan Test, K ratio = 100. Row means followed by same lower case letter not different using Waller-Duncan Test, K Ratio = 100.

[2] N or n indicates a non-significant F test for plant or soil treatment, respectively.

[3] Ratio of North New River Canal FL sediment:sand.

[4] Main effects.

reflecting the relatively larger root mass in eelgrass. Sediment treatment had little effect on these ratios, except for the decrease in hydrilla monocultures in sand due to reduced shoot growth.

This investigation was not intended to be a full-scale replacement series experiment because too few proportional combinations were used. However, the concept is useful in describing the interactions between hydrilla and eelgrass. Harper (1977, p 255-257) explains that interpretation of the results of experiments based on replacement series are based on the shape of the yield density curve for a single species. The results of the hydrilla-eelgrass experiments apply best to his Model IV which describes a beneficial relationship in which each species fails to suffer as much as expected from the presence of the other. Overall, the mixtures produce greater yields than would be expected from pure stands (monocultures). A straight line connecting the points of maximum yield of the individual species (Fig. 1, S1) defines the expected total yield of the mixture. The results as illustrated (Fig. 1, S1), indicate that total yield was greater than expected. The expected yields of the individual species are determined from a straight line connecting the data points at their y intercepts. Hydrilla yield was greater than expected, and eelgrass yield was as expected. This corroborates the earlier interpretation that eelgrass growth in sediment teatment S1 was not influenced by hydrilla grown in mixed culture; that interspecific competition had a positive influence on growth of hydrilla; and that hydrilla growth, in a relative sense, was negatively influenced by intraspecific competition.

Total yield of plant mixtures exceeded expected yields in each of the sediment treatments, as did hydrilla yield (Fig. 1). Growth of eelgrass was negatively influenced by hydrilla in treatment S2 since yield in the mixture was less than expected. Harper (1977, p 259-261) introduced the concept of Relative Yield Total (RYT) to describe mutual relationships of pairs of species regarding demands on environmental resources. The sum of Relative Yields (RY) of species is the RYT where RY = yield of the mixture/yield of the monoculture. When RYT = 1.0, demands are being made by both species on the same limiting resource(s). When RYT > 1.0, species make different demands on resources, avoid competition with each other or are showing some form of symbiotic relationship. An RYT value < 1.0 implies mutual antagonism. The RYT values calculated for sediment treatments S1 through S5 respectively were 1.27, 0.89, 1.32, 1.65 and 1.80. The antagonistic relationship observed in treatment S2 was expressed as an eelgrass yield less than expected when grown in mixed culture with hydrilla (Fig. 1).

Tissue Nutrient Concentration—Main effects (ME) statistics reveal that, except for Ca, concentration of macronutrients in tissue were higher in eelgrass than hydrilla (Table 3). The influence of mixed cultures on nutrient uptake was to increase P and Ca concentrations in hydrilla and to decrease N and K concentrations in eelgrass. The former was evidence of intraspecific

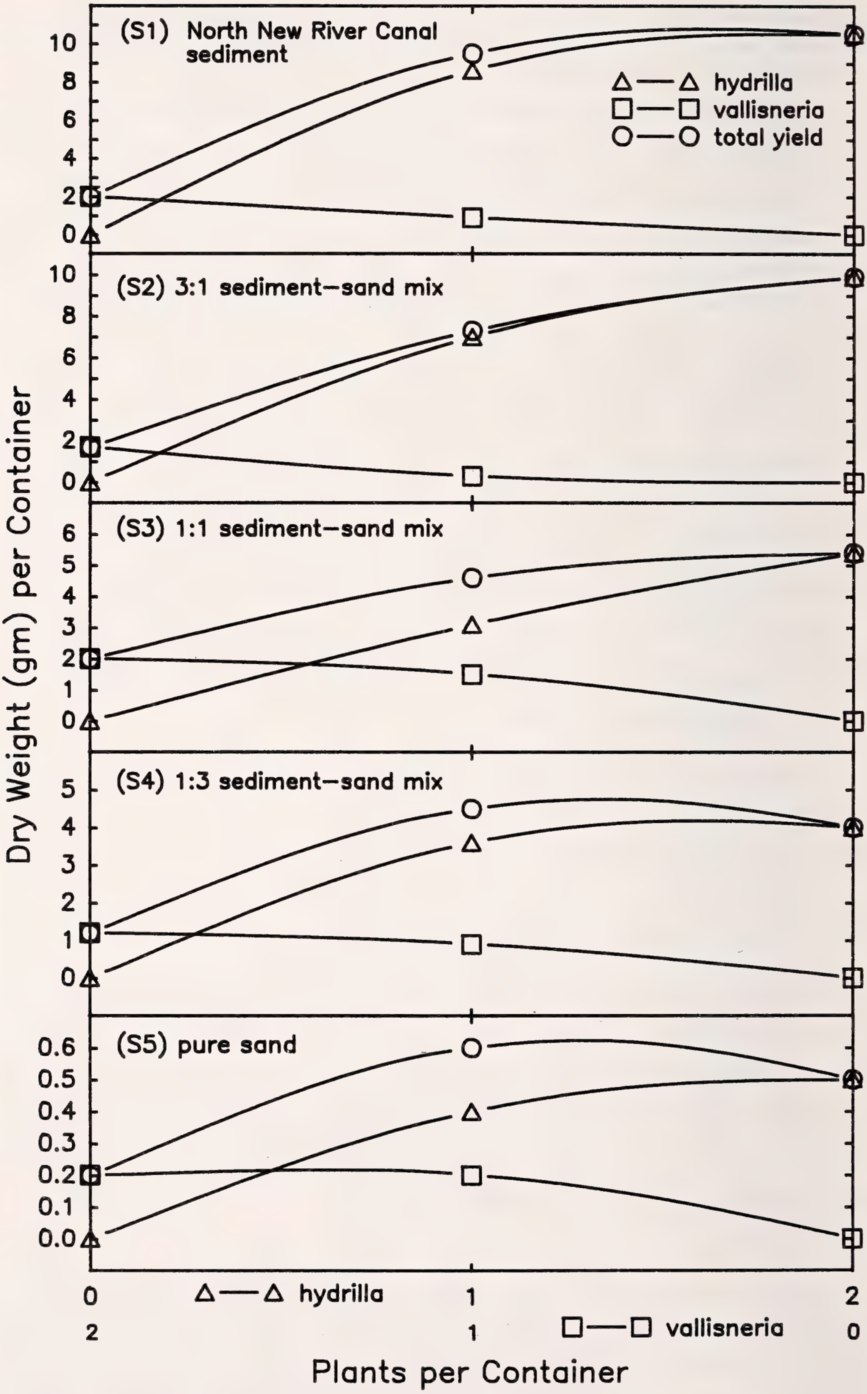

FIG. 1. Replacement series of hydrilla and eelgrass. Dry weight per container (78.5 cm^2 base area) of plants cultured in undiluted North New River Canal sediment (S1), 3:1 sediment-sand mix (S2), 1:1 sediment-sand mix (S3), 1:3 sediment-sand mix (S4) or undiluted sand (S5). Total yield represents the arithmentic sum of yields of both species.

interaction within hydrilla and the latter evidence of interspecific interaction between hydrilla and eelgrass. Tissue nutrient concentrations were not affected by sediment treatment except they were depressed when grown in the relative absence of nutrients in sand alone.

TABLE 3. Nutrient concentration (%) in shoot tissue of hydrilla or eelgrass grown in monoculture or in mixed culture (c) on soils of varying fertility.[1,2]

	S1[3] (1:0)	S2 (3:1)	S3 (1:1)	S4 (1:3)	S5 (0:1)	ME[4]-Plant
PHOSPHORUS						
Hydrilla	0.11Cn	0.10Bn	0.12Bn	0.14Nn	0.09Bn	0.11C
Eelgrass	0.25An	0.25An	0.21An	0.19Nn	0.25Bn	0.23C
Hydrilla(c)	0.19Ba	0.20ABa	0.20Aa	0.17Nab	0.14Bb	0.18B
Eelgrass(c)	0.28Aa	0.23ABab	0.23Aab	0.20Nab	0.10Bb	0.20AB
ME[4]-Soil	0.21a	0.19a	0.19a	0.17ab	0.15b	
NITROGEN						
Hydrilla	1.7Bn	1.4Bn	1.4Bn	1.6Bn	1.1Nn	1.5C
Eelgrass	3.3Aa	3.1Aab	2.5Ab	2.8Aab	2.0Nc	2.7A
Hydrilla(c)	1.5Bn	1.6Bn	1.9Bn	1.7Bn	1.9Nn	1.7C
Eelgrass(c)	2.8Aa	2.2ABa	2.5Aa	2.1Ba	1.3Na	2.2B
ME-Soil	2.3a	2.1a	2.1a	2.0a	1.5b	
POTASSIUM						
Hydrilla	3.3Bn	2.5Bn	2.7Bn	3.3Bn	1.9An	2.8C
Eelgrass	4.9Aa	5.0Aa	4.9Aa	4.9Aa	3.8Ab	4.7A
Hydrilla(c)	2.6Ca	2.7ABa	3.0Ba	2.1Ca	2.3Aa	2.5C
Eelgrass(c)	5.1Aa	3.3ABab	5.0Aa	4.6Aab	2.1Ab	4.0B
ME-Soil	4.0a	3.4b	3.9ab	3.8ab	2.5c	
CALCIUM						
Hydrilla	10.5An	11.5An	9.6An	8.5Bn	7.1Nn	9.4B
Eelgrass	4.1Bn	4.3Bn	3.8Bn	3.2Cn	5.8Nn	4.2C
Hydrilla(c)	11.3An	11.2An	10.0An	12.9An	10.7Nn	11.2A
Eelgrass(c)	4.9Bn	2.9Bn	4.8Bn	4.1Cn	5.2Nn	4.4C
ME-Soil	No difference between soils					
MAGNESIUM						
Hydrilla	0.18Cn	0.17Nn	0.16Bn	0.17Bn	0.11Bn	0.16B
Eelgrass	0.29Ba	0.30Na	0.33Aa	0.33Aa	0.34Aa	0.32A
Hydrilla(c)	0.17Cab	0.17Nab	0.18Ba	0.15Bb	0.16Bab	0.17B
Eelgrass(c)	0.32An	0.23Nn	0.32An	0.33An	0.22ABn	0.29A
ME-Soil	No difference between soils					

[1] Column means followed by same upper case letter not different using Waller-Duncan Test, K ratio = 100. Row means followed by same lower case letter not different using Waller-Duncan, K Ratio = 100.

[2] N or n indicates a non-significant F test for plant or soil treatment, respectively.

[3] See Table 2.

[4] Main effects.

Neither plant treatment nor sediment treatment significantly affected tissue concentrations of the micronutrients. The following range of values (mg/kg) were observed: Cu: 6 to 7 in eelgrass and hydrilla; Fe: 1380 to 2690 in eelgrass, 1600 to 3200 in hydrilla; Mn: 200 to 300 in eelgrass, 166 to 265 in hydrilla; Zn: 86 to 125 in eelgrass, and 50 to 80 in hydrilla.

Nutrient Accumulation—Amounts of macronutrients accumulated by plants (Table 4) are the products of tissue concentrations and dry weights and are based on weight of two plants in monoculture plant treatments. Accumulation was greatest in hydrilla since dry matter production by this plant was highest. Plant main effects (ME) statistics illustrate that, except for P, accumulation was greater in monoculture plant treatments. Phosphorus accumulation in hydrilla was decreased by sediment treatments S3 and S5 (Table 4), as was dry weight (Table 2). Accumulation was greater in hydrilla in sediment treatment S2 when grown in mixed culture, indicating competition from eelgrass was less than intraspecific competition. Accumulation of P by eelgrass followed the pattern of dry matter production. Only sediment treatment S5 affected P accumulation by eelgrass when grown in monoculture.

TABLE 4. Nutrient accumulation (mg) in shoot tissue of hydrilla or eelgrass grown in monoculture or in mixed culture (c) on soils of varying fertility.[1,2]

	S1[3]	S2	S3	S4	S5	ME[4]-
			PHOSPHORUS			
Hydrilla	11.8Aa	9.5Bab	6.3Abc	5.1Ac	0.8Ad	7.0B
Eelgrass	4.5Ba	4.2Ca	4.2ABa	2.2bAB	0.5ABb	3.1C
Hydrilla(c)	16.0Aa	14.0Aa	6.2Ab	6.3Ab	0.6ABc	8.6A
Eelgrass(c)	2.6Ba	1.3Cab	3.1Ba	1.6Bab	0.3Bb	1.9D
ME[4]-Soil	8.7a	7.7a	5.0b	3.8b	0.6c	
			NITROGEN			
Hydrilla	174Aa	137Aab	81Nbc	64Acd	10Ad	97A
Eelgrass	61Ba	53Ba	50Na	31BCab	4Bb	40C
Hydrilla(c)	134Aa	107Aa	56Nb	62ABb	8ABc	73B
Eelgrass(c)	28Bab	12Bab	37Na	19Cab	4Bb	21D
ME-Soil	99a	81a	56b	44b	6c	
			POTASSIUM			
Hydrilla	338Aa	245Ab	142Nc	116Ac	17Ad	180A
Eelgrass	94Ca	87Ba	96Na	56BCab	9Bb	68C
Hydrilla(c)	218Ba	188Aa	90Nb	79Bb	9Bc	117B
Eelgrass(c)	50Cab	21Bab	79Na	41Cab	6Bb	42D
ME-Soil	174a	143b	101c	73d	10e	
			CALCIUM			
Hydrilla	1085Aa	1137Aa	512Ab	361Abc	65Ac	662A
Eelgrass	93Ba	75Ca	78Ca	40Ba	17Ba	60C
Hydrilla(c)	955Aa	778Ba	312Bb	467Ab	47ABc	512B
Eelgrass(c)	49Ba	17Ca	78Ca	35Ba	16Ba	42C
ME-Soil	545a	534a	244b	225b	36c	
			MAGNESIUM			
Hydrilla	18.6Aa	17.2Aa	8.8Nb	6.5Abc	1.0Nc	10.9A
Eelgrass	5.6Ba	5.3Ba	6.5Na	3.7ABab	0.7Nb	4.4C
Hydrilla(c)	14.3Aa	12.1Aa	5.6Nb	5.7ABb	0.7Nc	7.7B
Eelgrass(c)	2.9Bab	1.3Bab	5.1Na	2.8Bab	0.7Nb	2.7C
ME-Soil	10.4a	9.5a	6.5b	4.7b	0.8c	

[1] Column means followed by same upper case letter not different using Waller-Duncan Test, K ratio = 100. Row means followed by same lower case not different using Waller-Duncan Test, K Ratio = 100.

[2] N or n indicates a non-significant F test for plant or soil treatment, respectively.

[3] See Table 2.

[4] Main effects.

Nitrogen accumulation was reduced in hydrilla by sediment treatment S3 and S5, but only by S5 in eelgrass. Number of plants did not effect nitrogen accumulation by individual species. There were no apparent interspecific competitive interactions.

Potassium accumulation was reduced in hydrilla when grown in mixed culture with eelgrass in treatments S1, S4, and S5. This was supported by plant ME statistics. Sediment treatments had a greater effect on K accumulation in hydrilla. Quantities were reduced by treatments S2, S3, and S5 in hydrilla grown in monoculture but only by S3 and S5 when grown in mixed culture. Potassium accumulation in eelgrass was little affected by sediment treatment. Generally, reductions occurred only in sand treatments (S5).

Calcium accumulation in hydrilla decreased with decreasing sediment fertility whereas eelgrass was unaffected. Magnesium accumulation in hy-

TABLE 5. Mehlich extracted nutrients from pretreatment (initial), posttreatment (Pl, P2, P3) and control (Leached) soils utilized in plant growth study and soil pHs.[1,2]

	S1[3]	S2	S3	S4	S5	ME[4]-
			PHOSPHORUS (ug/g)			
Initial	5.4ABd	13.0Ad	41.2Nc	105.0Nb	137.8Na	60.5AB
Leached	6.5Ad	9.2Bd	50.8Nc	118.5Nb	144.2Na	65.8A
Hydrilla (P1)	4.0Cd	4.5Dd	38.8Nc	112.0Nb	150.5Na	61.9AB
Eelgrass(P2)	4.9BCd	5.9Cd	41.0Nc	114.5Nb	147.8Na	62.8AB
Both (P3)	4.6BCd	6.1Cd	44.5Nc	107.5Nb	124.5Na	57.4B
ME[4]-Soil	5.1d	7.7d	43.2c	111.5b	140.9a	
			MAGNESIUM (ug/g)			
Initial	460Aa	469Ba	382Ab	240ABc	61.0Bb	322A
Leached	453ABb	497Aa	358Ac	234ABd	65.5Be	322A
Hydrilla(P1)	451ABb	484ABa	387Ac	226Bd	73.8Ae	324A
Eelgrass(P2)	380Cd	477ABa	326Ab	294Ac	62.8Bd	308A
Both(p3)	412BCd	464Ba	364Ac	240ABd	62.0Be	308A
ME-Soil	431b	478a	363c	247d	65e	
			CALCIUM (mg/g)			
Initial	28.1ABa	28.2Na	27.5Na	22.3Nb	10.9BCc	23.4N
Leached	27.8ABa	28.5Na	26.5Nb	21.6Nc	11.5BACd	23.2N
Hydrilla(P1)	28.6Aa	28.6Na	26.8Nb	22.2Nc	12.1ABd	23.7N
Eelgrass(P2)	27.2Bab	28.7Na	24.7Nb	24.5Nb	12.4Ac	23.5N
Both(P3)	28.2ABa	28.5Na	26.4Nb	22.6Nc	10.6Cd	23.3N
ME-Soil	28.0a	28.5a	26.4b	22.6c	11.5d	
			POTASSIUM (ug/g)			
Initial	56.5Ba	35.8Bb	22.8Cc	14.0ABd	2.2Ce	26.2B
Leached	34.8Ca	28.2Bb	22.0Cc	12.8Bd	2.5Ce	20.0C
Hydrilla(P1)	74.5Aa	61.0Ab	31.8ABc	21.5ABd	5.8Ae	38.9A
Eelgrass(P2)	52.5Bab	59.0Aa	27.5BCcd	30.0Abc	4.8ABd	34.8A
Both(P3)	74.0Aa	54.0Ab	36.5Ac	24.0ABd	3.8BCe	38.4A
ME-Soil	58.4a	47.6b	28.1c	20.4d	3.8e	
			pH[5]			
Initial	7.6Ca	7.6Db	7.7Dc	7.7Cc	8.0Cd	7.7D
Leached	7.5Ca	7.5Ca	7.5Ca	7.5Ba	7.8Bb	7.6C
Hydrilla(P1)	7.4Bb	7.4Bb	7.3Bab	7.3Aa	7.6Ac	7.4B
Eelgrass(P2)	7.3Aa	7.3Aa	7.2Aa	7.2Aa	7.7ABb	7.3A
Both(P3)	7.4Bbc	7.4Bc	7.3Bab	7.3Aa	7.6ABb	7.4B
ME-Soil	7.4b	7.4b	7.4a	7.4a	7.7c	

[1] Column means followed by same upper case letter not different using Waller-Duncan Test, K ratio = 100. Row means followed by same lower case letter not different using Waller-Duncan Test, K Ratio = 100.

[2] N or n indicates a non-significant F test for plant or soil treatment.

[3] See Table 2.

[4] Main effects

[5] ANOVA performed on hydrogen ion concentration.

drilla was reduced by treatment S3, S4, and S5. Only treatment S5 affected accumulation by eelgrass grown in monoculture. Plant numbers did not affect accumulation by individual species.

Mehlich Sediment Nutrients—The concentrations of sediment macronutrients were measured (Table 5) in extracts utilized in the Mehlich procedure (Jones, 1980). Initial concentrations of P in sediments were directly related to the proportion of sand in the sediment mix. Because of the amounts of sand utilized and because of the difficulty in obtaining homogeneous mixtures with wet sand, sand used for sediment mixtures was not washed prior to use. The sand may have been contaminated with P as there are extensive P deposits in Florida and occasionally these are found adjacent to sand deposits. Phosphorus appeared to be leached only from S2 sediment treatment by flowing water. However, heavy algae growth, which only occurred on the surface of sediments without plants, may have been responsible for this reduction. Hydrilla growth in P1 (Table 5) reduced P below initial levels in S1 and S2. Eelgrass (P2) and the mixed culture (P3) reduced P levels when grown in S2.

Magnesium concentrations were not reduced by flowing water nor by growth of hydrilla. The Mg concentration was reduced, however, by eelgrass and by the plant mixed culture (S1). Water flow increased Mg concentration in one soil treatment (S2). Calcium levels were generally not affected by plant growth or by water flow.

The amount of K leached from soil treatment S1 was sufficient to produce a significant main effects reduction. Potassium concentrations were increased by hydrilla growth in all sediment treatments except S4, and by eelgrass in S2 and S5. Initial and sediment ME levels indicate an orderly decrease from S1 through S5.

Initial pH of sediments increased with increasing sand content. The pH was decreased in all sediments, except S1, by flowing water. The pH was further decreased by growth of plants, with the greatest reduction having been caused by eelgrass. The greater decrease in pH caused by eelgrass may be related to larger root mass of this species (Table 2). Sediment main effects statistics indicate lowest pH occurred on S3 and S4, next on S1 and S2 and were highest on S5. This was essentially the pattern for hydrilla and the mixed culture. There were no differences across sediments for eelgrass except for increased pH on S5. This relationship may be due to reduced growth on sands indicating reduced root respiration with lower hydrogen ion production.

Nutrient Content of Sediments—The amount of individual nutrients in the treatment sediments was calculated utilizing the concentration of the element in the sulfuric acid-peroxide digests of the sediment, and the estimated weight of the sediment replicate (Table 6). In comparing the amounts of nutrients accumulated by growing plants (Table 4) with the amounts of available sediment nutrients (Table 6), it is obvious that supplies of sediment nutrients were adequate to support plant growth, except for potassium. Accumulation of this element by hydrilla exceeded sediment supplies indicating K was supplied from ambient water.

TABLE 6. Estimated total nutrient content of pretreatment experimental sediments.

Nutrient Element (mg)	Sediment Treatments S1 (1:0)[1]	S3 (1:1)	S5 (0:1)
Nitrogen	1,044 ± 30[2]	328 ± 10	0
Phosphorus	116 ± 0	361 ± 20	551 ± 10
Potassium	186 ± 0	98 ± 0	42 ± 10
Magnesium	789 ± 20	393 ± 20	127 ± 0
Calcium (gm)	22 ± 1	19 ± 1	15 ± 1
Copper	7 ± 1	4 ± 0	2 ± 1
Manganese	17 ± 0	9 ± 0	5 ± 0
Iron	234 ± 10	112 ± 0	22 ± 0
Zinc	22 ± 6	9 ± 0.5	9 ± 1

[1] Ratio of North New River Canal FL sediment: builders sand.
[2] Mean ± standard errors of 4 replications.

The Mehlich procedure underestimated available P in sediment by at least 1233% since little or no P was available from ambient water. The maximum amount of P accumulated by hydrilla was approximately 14% of the P supply in sediment (S1) as estimated in the sulfuric acid-hydrogen peroxide digests. The rationale for the use of chemical sediment extracts is that they mimic the plant in harvesting available nutrients. This is complicated in rooted aquatic plants since both roots and foliage function in nutrient uptake. In terrestrial plants, nutrients are principally absorbed by roots. The Mehlich procedure detected reductions of P in S1 and S2 presumably caused by plant growth as well as reductions in Mg in S1 by eelgrass (Table 5). In general, however, the procedure was insensitive and would not be recommended for aquatic sediments.

Hydrilla biomass production was approximately five times that of eelgrass, when grown in monoculture on undiluted sediment. When nutrient content of sediment was reduced by dilution with sand, hydrilla biomass was reduced, though not proportionately. Eelgrass however, was not affected by decreased fertility of sediment, except when grown on relatively infertile pure sand, indicating that nutrient requirements may be lower than for hydrilla. When hydrilla and eelgrass were grown in mixed culture, hydrilla biomass was greater than when paired with another hydrilla plant. This is evidence that intraspecific competition was more effective in reducing growth than was competition from eelgrass (interspecific). Growth of eelgrass was not affected when combined with hydrilla, however eelgrass shoot weight tended to increase when sediment fertility and hydrilla growth were reduced, indicating possible growth suppression by hydrilla under conditions of maximal biomass production.

The specific factors involved in producing the observed growth responses were not obvious. Eelgrass exhibited a greater ability to concentrate nutrients in tissues, but there was no obvious relationship to sediment fertility, except on pure sand. Accumulation of nutrients by plants was most closely related to biomass production, being greatest in hydrilla. No one specific nutrient element could be categorized as being limiting. Sediment-P content was inversely related to biomass production of hydrilla. Sediment-K reserves were inadequate but potassium was apparently available from ambient water. Nitrogen was deficient in sand but appeared adequate in treatment S3, which produced a significant growth reduction in hydrilla. Tissue-N concentration of hydrilla in this treatment was identical with treatment S2, which produced a higher biomass. Magnesium and calcium supplies appeared to be adequate. Concentrations of minor elements in hydrilla tissues were nearly identical in all sediment treatments. Copper concentrations appeared to be low in treatment sediments but they apparently were adequate, (at least in treatments S1 and S2). Concentration of copper in tissues was present at levels normally occurring in healthy wild plants (Sutton et al., 1971).

The results of analyses of Potomac River sediments show that supplies of mineral elements required for nutrition of plants should be more than adequate to support growth of both hydrilla and eelgrass. Total-P supplies, for example, were 2 to 8 times higher than in the Florida North New River Canal sediment (Table 1); the latter, undiluted, produced maximum biomass experimentally.

The interactions between hydrilla and eelgrass observed in this investigation indicate that competition for nutrients should not be a factor affecting competitive displacement of one plant by the other under similar growth conditions.

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LITERATURE CITED

Allen, S., H. M. Grimshaw, J. A. Parkinson, and C. Quarmby. 1974. Chemical analysis of ecological materials. John Wiley & Sons. New York.

Apha. 1985. Standard Methods for the Examination of Water and Wastewater. 16th Ed., APHA, AWWA, WPCF, American Public Health Asso., Washington, D.C.

Barko, J. W. and R. M. Smart. 1980. Mobilization of sediment phosphorus by submersed freshwater macrophytes. Freshwater Biol. 10; 229-238.

_________ and R. M. Smart. 1983. Effects of organic matter additions to sediment on the growth of aquatic plants. J. Ecol. 71:161-175.

_________ and R.M. Smart. 1986. Sediment-related mechanisms of growth limitation in submersed macrophytes. Ecology. 67(5):1328-1340.

Black, C.A. (ed.). 1965. Methods of Soil Analysis, Part 1. pp. 562-567. Amer. Soc. Agron., Inc. Madison, WI.

Carinhan, R. and J. Kalff. 1980. Phosphorus sources for aquatic weeds: water or sediments? Science 20-7:987-989.

Chen, R. L. and J. W. Barko. 1988. Effects of freshwater macrophytes on sediment chemistry. J. Freshwater Ecol. 4(3):279-289.

Cox, G. W. 1967. Laboratory Manual of General Ecology. pp. 149-154. Wm. C. Brown Co. Dubuque, IA.

Frank, P. A. and N. Dechoretz. 1980. Allelopathy in dwarf spikerush *(Eleocharis coloradoensis).* Weed Sci. 28:499-505.

Haramis, G. M. and V. Carter. 1983. Distribution of submersed aquatic macrophytes in the tidal Potomac River. Aquat. Bot. 15:65-79.

HARPER, J. L. 1977. Population Biology of Plants. Academic Press, New York.

JONES, J. B., JR. (ed.). 1980. Handbook on Reference Methods for Soil Testing. The Council on Soil Testing and Plant Analysis. Univ. Georgia. Athens, GA.

MILLAR, C. E., L. M. TURK, AND H. D. FOTH. 1958. Fundamentals of soil science. John Wiley & Sons, Inc. New York. p. 48.

PEECH, M. 1965. Hydrogen-ion activity. Pp. 914-925. *In:* BLACK, C. A. (ed.). Methods of Soil Analysis. Part 2. American Society of Agronomy, Inc. Madison, WI.

RICE, E. L. 1974. Allelopathy. 2nd ed. Academic Press, Orlando, FL.

RYBICKI, N. AND V. CARTER. 1986. Submersed macrophytes in the tidal Potomac River: Implications for water quality and wildlife. Proc. Symp. Freshwater Wetlands and Wildlife U.S. Geol. Survey, Reston, VA

________, R. T. ANDERSON, J. M. SHAPIRO, K. L. JOHNSON, AND C. L. SCHULMAN. 1987. Data on the distribution and abundance of submersed aquatic vegetation in the tidal Potomac River and estuary, Maryland Virginia, and the District of Columbia, 1986. U.S. Dept. of the Interior, U.S. Geological Survey Open-File Report 87-575. Reston, VA. 82 pp.

________ AND V. CARTER. 1987. Field studies of submersed aquatic vegetation in the Potomac River (Abstract). p. 264-265. *In:* Proceedings, 21st Annual Meeting, Aquatic Plant Control Research Program. Miscellaneous Paper A-87-2. U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS.

STEWARD, K. K. 1984. Growth of hydrilla *(Hydrilla verticillata)* in hydrosoils of different composition. Weed Sci. 32:371-375.

________, T. K. Van, V. Carter, and A. H. Pieterse. 1984. Hydrilla invades Washington, D.C. and the Potomac. Amer. J. Bot. 71:162-163.

SUTTON, D. L. 1982. A core sampler for collecting hydrilla propagules. J. Aquat. Plant Manage. 20:57-59.

________, R. D. Blackburn, and K. K. Steward. 1971. Influence of herbicides on the uptake of copper in *hydrilla*. Weed Research 11:99-105.

YEO, R. R., AND J. R. THURSTON. 1984. The effect of dwarf spikerush (Eleocharis coloradoensis) on several submersed aquatic weeds. J. Aquat. Plant Manage. 22:52-56.

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RADIUM AND RADON IN DADE COUNTY GROUND WATER AND SOIL SAMPLES

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Abstract: *Both the National Uranium Resource Evaluation and the Florida Statewide Radiation studies indicated a high potential for elevated indoor radon-222 activity levels in Dade County. This was confirmed by readings in one home which exceeded 40 pCi/L. Radium-226 and Radon-222 concentrations were determined in ground water and soil samples in order to understand better the cause of this apparent anomaly. Results indicate the radon-222 source materials are of natural origin, concentrated near the surface, primarily in a region in south Dade County known as the Redlands.*

In the mid-1980's concern developed about potential contamination of homes and buildings by naturally occurring, radioactive radon-222 gas. The incident that stimulated much of this concern occurred in December, 1984 when Stanley Watras, an engineer at a nuclear power plant in eastern Pennsylvania, set off radiation monitors as he entered the plant (Cohen, 1987). Investigations revealed that the Watras home had radon-222 levels of 2700 pCi/L. The Environmental Protection Agency has set maximum indoor exposure levels at 4.0 pCi/L. The radon found in the Watras home came from an exposed vein of uranium ore directly below the house.

Radon-222 is a naturally occurring radioactive element, with a half-life of 3.82 days. It is the daughter product of radium-226 ($t_{1/2}$ 1600 years) and the only gaseous element in the uranium-238 decay series.

Motivated by the high radon-222 levels found in the Watras home, the EPA initiated extensive radon-222 surveys in several states. Florida, which was not included in the EPA's nationwide study, initiated its own study in 1986 to determine the potential for indoor radon-222 contamination across the state (Nagda et al., 1987). It was already known that the phosphate mining region in central Florida had a high potential for indoor radon-222 contamination. As a result of the study, Dade County, and in particular an area in the vicinity of Homestead, was identified as having definite evidence of elevated radon-222 potential. The results obtained were not expected based on the known geology of the area.

The purpose of the present study was to examine more closely the radon-222 anomaly in south Dade County. This area is of particular interest as it is gradually changing from a predominantly agricultural area to suburban housing. Collection and analysis for radium-226 and radon-222 of soil and ground water samples from selected sites within Dade County was carried out to ascertain the distribution and origin of radon-222 source materials.

National Uranium Resource Evaluation—In 1974, the National Uranium Resource Evaluation (NURE) program was established by the U.S. Department of Energy (DOE) to determine the location and magnitude of uranium

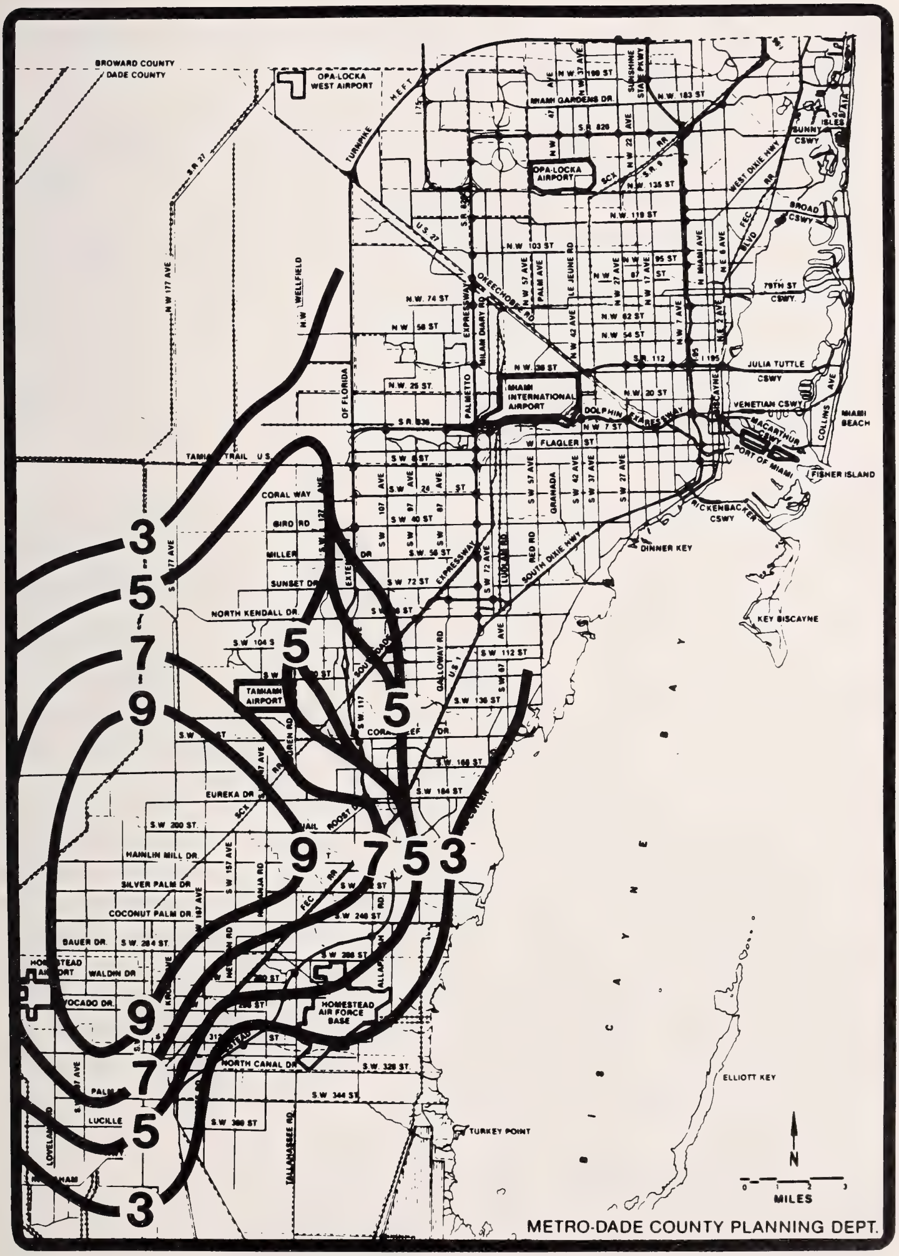

FIG. 1. NURE survey contours. Values are given in ppm uranium.

resources within the United States suitable for future economic development. Declining uranium market conditions coupled with federal fiscal policies caused the NURE program to be curtailed in the early 1980s.

Before curtailment of the NURE program, an aerial gamma radiation survey of the Miami and Key West quadrangles was completed (USDOE, 1981). The aerial mapping process detects radiation emanating from the top 18 inches of land surface, thus the NURE results for uranium indicate near-surface sources of radon-222.

The NURE survey indicated several anomalies in the Miami quadrangle,including one located in south Dade County in the vicinity of Homestead with peak values for uranium ranging from 3.6 to 5.1 ppm (Fig. 1). These values are low when compared with the 120 ppm Florida phosphate rock (Eisenbud, 1987) and the 1000 ppm for mining ore deposits (McKelvey et al., 1955), however, the Dade County values are higher than values for much of the remaining area and the 1 to 2 ppm average uranium concentration for the Earth's crust.

Florida Statewide Radiation Study—The purpose of the Florida Statewide Radiation Study was to identify those areas where indoor radon-222 levels could be expected to exceed the Florida standard of 0.02 working level (equivalent to 4 pCi/L).

Based on the information which already existed and the results gathered during county-by-county surveys, each county was placed into one of three categories according to their potential for elevated radon-222: (1) Definite evidence (18 counties); (2) Limited evidence (14 counties); (3) No evidence (35 counties). Dade County was classified among those counties having definite evidence of elevated radon-222 potential. Four USGS quads, located adjacent to each other near the center of Dade County, were classified in category 1 (Nagda et al., 1987). Two of these four USGS quads correspond to areas having elevated soil uranium concentrations in the NURE study.

Summary of Geologic Features—Dade County is located in what is known as the Coastal Lowlands section of Florida typified by low elevations, nearly flat terrain, and the presence of marshlands or swamps. Two features dominate the topography of Dade County, the Atlantic Coastal Ridge and the Everglades. The Atlantic Coastal Ridge runs the length of the state, along the east coast, from south Dade to the Georgia border. The Everglades, a great depression covering much of South Florida, has a maximum elevation above sea level of little more than five feet within Dade County (Hoffmeister, 1974). The Everglades is a vital recharge area for the shallow Biscayne Aquifer, the source of fresh irrigation and drinking water for many farmers and residents of South Florida.

The predominant geologic formation underlying Dade County, referred to as Miami Limestone, dates from the Pleistocene age, 10 thousand to 1.8 million years ago. This formation has two components: the inorganic oolitic facies and the bryozoan facies of organic origin. The oolitic mass which forms the Atlantic Coastal Ridge partially overlays the bryozoan facies and extends throughout most of the county as the predominant bedrock. The bryozoan facies which underlies much of the Everglades replaces the oolite as the predominant bedrock in areas of western Dade County. Quartz sand, ranging in color from grayish white to dark brown and believed to be remnants of the

Pamlico Formation, may be found in varying depths overlying the limestone formations of South Florida (Hoffmeister, 1974).

The oolitic limestone of South Florida began to develop approximately 100,000 years ago at a time when the sea level had risen 25 feet above its present level. Tiny egg shaped granules of calcium carbonate, or ooids, precipitated from seawater to form a huge bar. Tidal channels, referred to as "glades", cut perpendicular across the length of the bar. During the Wisconsin Ice Age, the sea level dropped and the layers of ooids were left exposed and subsequently subjected to the weathering cycle.

The bryozoan facies is primarily composed of calcareous cellular structures which housed very small reddish marine animals known as bryozoans. The bryozoan facies also contains calcareous tubes and excretory pellets from marine worms as well as ooids like those in the oolitic facies.

Over time, portions of the carbonate deposits were dissolved by rain and reprecipitated in cracks and crevices. Eventually, the individual granules, pellets, and calcareous masses were cemented together into hard, very porous rock through this process. Continued weathering of the Miami Limestone has produced a karstic surface. Karstic features appear to be more pronounced in south Dade County. Sink holes and solution pits ranging up to three meters deep have been found and are often filled with sand and soil (Halley and Evans, 1983).

Dade County Soil—Dade County soils are for the most part composed of limestone and sand of marine origin in addition to organic and inorganic materials from other sources. The soil covering in many parts of Dade County is typically thin to nonexistent. Soils found in Dade County have been classified into 15 major categories and further subdivided within those categories into a total of 43 distinct soil types (U. S. Dept. of Agriculture, 1958). In South Dade, soils of primary concern are the Perrine marl and Rockdale series. Perrine marl is the soil found in the low lying "glades" which cut through the higher ridge areas of South Dade. The Rockdale series may be found on or along the higher ridge terrain in areas associated with the natural slash pine forests of earlier years. One area in south Dade County where the Rockdale soil is predominant has become known as the "Redlands" due to the soil's reddish-brown color. Such reddish-brown soils, called terra rossae, have an iron oxide component and are typically found on karstic limestone such as found in South Dade (Strom and Kim, 1987; Hunt, 1972).

Methods—Soil samples were collected from a variety of locations including farmlands, orchards, residential yards, roadways, and relatively undisturbed areas in parks located within Dade County. Several varying samples of soil were gathered at some sites. Most of the samples were taken in natural slash pine or oak hammock areas not likely to have been disturbed through the addition of fill or phosphate fertilizers. Surface samples were obtained by scraping the soil and rock to a depth of five centimeters, mixing the scrapings, and then placing a small portion of the mixed soil scrapings into plastic sample bags.

During the course of this work a case similar to that of the Watras incident occurred. A worker in the Turkey Point Nuclear Plant set off radiation detectors in the plant (Jennings, 1988). His home in South Dade County was found to have indoor radon-222 levels exceeding 40 pCi/L. Samples from that location are included in this study.

Depth profiles were taken at three locations. At the first site, a sample of rock from the bottom of a recently dug well (7.6 meters) was obtained. At the second site, four samples were taken at 15 centimeter intervals to a depth of 60 centimeters. For the remaining soil profile, well core samples from a USGS well drilling program site, at 0.6 meter intervals to a depth of 3.6 meters, were obtained.

Analytical methods were based on standard laboratory methods of analysis for radium-226 and radon-222 (Lucas, 1957). Radon was transferred from a gas bubbler containing the sample into a Lucas counting cell through the use of a radon-222 transfer system. Alpha activity was then determined using a scintillation counting system.

Shallow irrigation wells with easy accessibility to the aquifer were used for sampling ground water. Water from the wells was pumped into bubblers by means of a hand-driven tubing pump using plastic tubing which was weighted and lowered into each well to a point below the water level, but above the bottom of the well. The bubblers were tightly sealed to prevent the loss of any excess radon-222, the activity of radon-222 in the sample not supported by radium-226, and transported to the laboratory for analysis. The water samples were analyzed within two days for excess radon-222. The bubblers were then resealed and allowed to stand for ingrowth of radon-222 from the radium-226. The water samples were analyzed for radium-226 by repeating the outgassing and counting process.

Two of the water samples were analyzed for gross alpha and gross beta activity by evaporating one hundred-mL portions of the sample to dryness on a planchet. The dried samples were then counted in a windowless, flow-through proportional counter.

After removing large pieces of organic matter, the soil samples were ground using an iron mortar and pestle. Approximately 5 g. was dried overnight at 105°C and then reweighed. This portion was placed in a muffle furnace at 900°C for several hours to remove organic material and destroy carbonate (Pierce and Haenisch, 1948). Concentrated hydrochloric acid was used to dissolve the sample. An undissolved residue that remained in some samples was analyzed using a microprobe analyzer and found to be silica. The samples were transferred with deionized water into gas bubblers and stored to allow for ingrowth of radon-222. At the conclusion of the ingrowth period, the samples were outgassed and counted.

Determination of radon-222 transfer and counting efficiency was accomplished by comparison to standard radium-226 solutions obtained from the National Bureau of Standards. These standards were kept in gas bubblers and outgassed in the same manner as the samples. A Ra-DEF alpha/beta standard from Nuclear Measurements Corporation and a Gd-148 alpha standard from the National Bureau of Standards were used to calibrate the proportional counter. One standard deviation errors in all values given are estimated from counting statistics and transfer efficiencies to be less than 5 percent of the value listed for each sample.

RESULTS—Excess radon-222 and radium-226 activities for the ground water samples collected in south Dade County are shown (Table 1). Gross alpha and beta results on ground water are also given (Table 2). The samples labeled A and B are from two different wells at the same site.

Radium-226 analyses for 88 soil and rock samples collected in Dade County are shown (Tables 3 and 4). Multiple soil samples taken at a location are indicated by letters which follow the location number. The locations where soil samples were collected are shown (Fig. 2). Water samples were collected in the region indicated by soil sample locations 32 through 35 and 39 through 45.

DISCUSSION—For the ground water samples, excess radon-222 ranged from 62.0 to 147.4 pCi/L. These values are much lower than the typical levels of 1000 pCI/L radon-222 found in well waters in the United States (Cohen, 1987).

The concentration of radium-226 in the ground water samples ranged from 0.30 pCi/L to 0.89 pCi/L. The EPA has set limits on the combined concentrations of radium-226 plus radium-228 of 5 pCi/L of water. Since the

TABLE 1. Radon-222 and radium-226 content of ground water.

Sample Location	Rn-222 pCi/L	Ra-226 pCi/L
1	91.9	0.48
2	139.4	0.56
3 A	63.1	0.89
3 B	122.5	0.61
4	lost	0.35
5	70.8	0.57
6	101.4	0.44
7	81.7	0.53
8	147.8	0.44
9	85.2	0.32
10	73.8	0.42
11 A	62.3	0.36
11 B	94.9	0.58
12	84.8	0.56
13	64.2	0.30
14	91.2	0.62
mean	91.7	0.50

activity of radium-228 found in ground water is typically less than the activity of radium-226, the samples from south Dade County appear to be low in both of these radionuclides.

Gross alpha and gross beta activities are used to determine compliance with EPA drinking water standards applicable to community water systems. For the three samples tested, the gross alpha activity ranged from 0.50 to 1.27 pCi/L and the gross beta activity ranged from 6.8 pCi/L to 14.5 pCi/L. All of the above activity values are below the EPA maximum contaminant levels. Thus the levels of radioactivity found in the ground water are not of concern for homes using this water.

Several broad generalizations concerning the radium-226 content of soils in Dade County can be made from the samples analyzed. Concentrations of radium-226 in sedimentary limestone are typically less than 0.5 pCi/g. The concentration of radium-226 in the surface soil samples from Dade County ranged from 0.13 pCi/g to 8.69 pCi/g with a mean value of 1.54 pCi/g. The values for south Dade County, particularly in the vicinity of Homestead, are higher than for other areas. The samples exceeding 8 pCi/g in radium-226 were taken from locations within the contour of the highest uranium levels found in the NURE study. In addition, zip code 33030, identified in the Florida Statewide Radiation Study as having high levels of radon-222, aver-

TABLE 2. Gross alpha and beta results for ground water.

Sample Location	Gross Alpha pCi/L	Gross Beta pCi/L
5	1.27	12.9
9	0.88	14.5
14	0.50	6.8

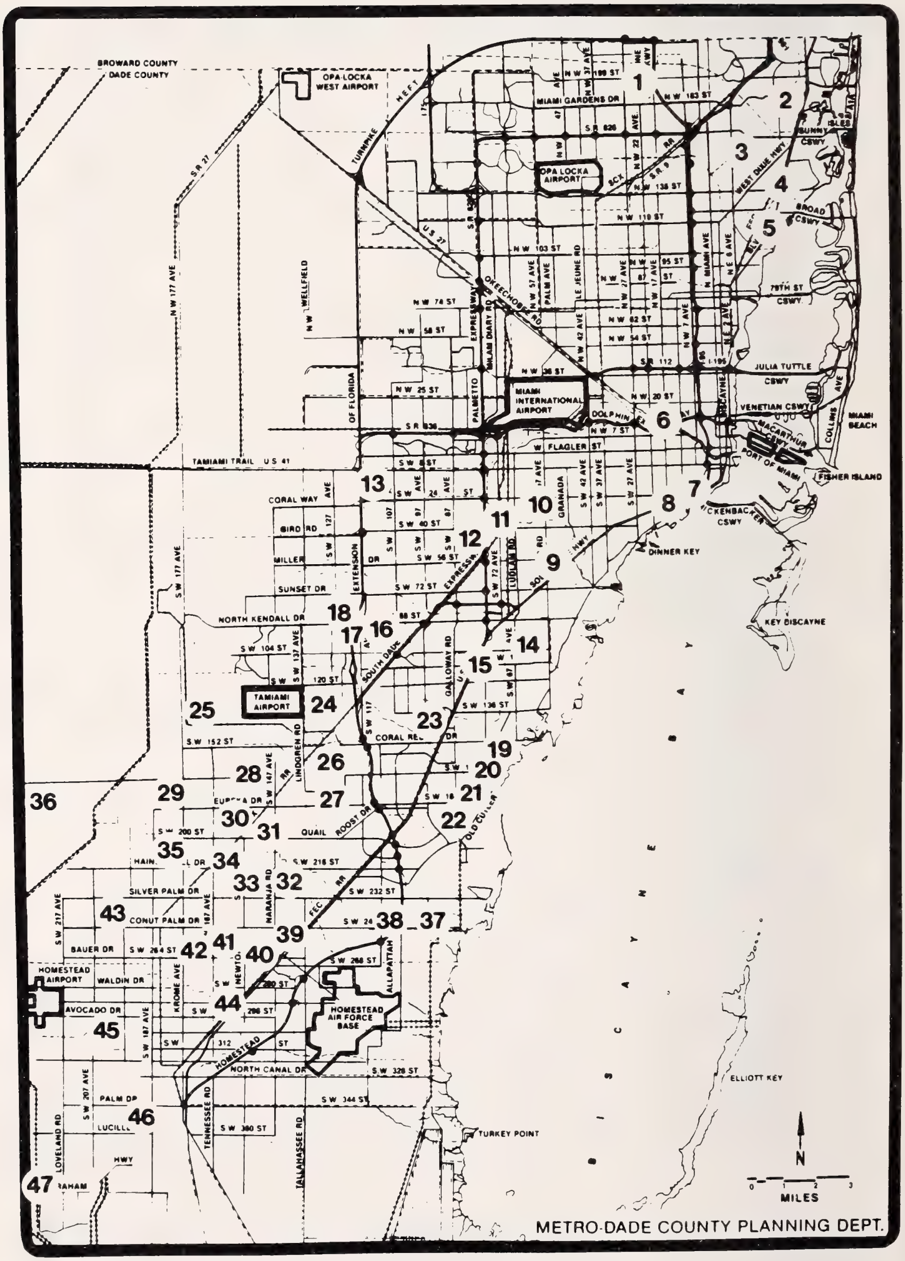

FIG. 2. Soil sample locations.

aged 3.20 pCi/g in radium-226 while adjacent zip codes 33031 and 33170, which were not in the Florida survey, averaged 3.14 pCi/g and 3.49 pCi/g in radium-226, respectively.

TABLE 3. Radon-226 content of Dade County surface soils.

Sample Location	Ra-226 pCi/g	Sample Location	Ra-226 pCi/g
1	0.80	27 A	0.75
2 A	0.43	27 B	1.26
2 B	0.31	28	1.36
2 C	0.13	29	0.76
2 D	0.40	30	0.63
3	0.33	31	2.81
4 A	0.70	32	1.17
4 B	0.28	33 A	0.61
5	0.74	33 B	8.69
6 A	0.56	34	1.09
6 B	0.45	35	0.61
7 A	0.77	36 A	2.84
7 B	0.52	36 B	0.90
8 A	1.08	* 37 A	1.46
8 B	2.31	38	0.58
8 C	0.48	39	4.31
8 D	0.31	40	1.02
9	0.86	* 41 A	0.17
10	0.86	42 A	2.92
11	0.73	42 B	0.91
12 A	0.77	42 C	0.43
12 B	2.28	42 D	0.91
13	0.56	42 E	1.30
14	0.96	43 A	8.24
15	0.69	43 B	3.51
16	0.69	43 C	6.87
17	0.59	44 A	1.43
18	0.67	44 B	1.44
19	0.21	45 A	4.49
20	1.11	45 B	4.21
21	2.16	45 C	1.84
22	0.57	* 45 D	5.92
23	0.63	46 A	1.86
24	0.45	46 B	1.41
25 A	0.99	47 A	1.70
25 B	2.33	47 B	2.02
26 A	1.53	47 C	1.65
26 B	1.30	47 D	1.40
26 C	1.40	47 E	0.75
26 D	2.41		

*Surface readings for profile sampling locations.

In Dade County, it is very hard to make a distinct separation of soil from bedrock. In many instances agriculture is carried out by simply discing the bedrock, adding fertilizer and planting. Thus samples may be a mixture of recognized soils and bedrock. Color appears to be a very important characteristic in characterizing the high radium soils in the area. Color varies from white for the Miami Limestone; to light gray, brown or red, and dark brown to almost black for the Rockdale; to gray for the Perrine Marl. The reddish-brown Rockdale surface soil samples (terra rossa) generally had higher radium activities than samples of other colors. This soil type is most commonly associated with the Redlands area of south Dade County. Not all of the Rockdale soil is red nor high in radium-226. Rather, the Rockdale soil that is high in radium-226 occurs mainly west of the Atlantic Coastal Ridge. Perrine Marl found in the low lying "glades" and along the coast south and east of the Atlantic Coastal Ridge appears to be lower in radium-226 content.

TABLE 4. Sampling profiles.

Sample Location	Depth, cm	Ra-226 pCi/L	Comments
Agricultural Field			
45 D	surface	5.92	Rockdale soil
45 E	760	0.83	at surface
Agricultural Field			
37 A	0-15	1.46	Perrine marl
37 B	15-30	1.52	at surface;
37 C	30-45	0.52	Rockdale
37 D	45-60	3.54	at base
USGS Well Core Profile			
41 A	0-60	0.17	Miami limestone
41 B	60-120	0.36	at all levels;
41 C	120-180	0.36	white color;
41 D	180-240	0.44	no silica
41 E	240-300	0.73	content
41 F	300-360	0.49	

The fine sand soils do not appear to be high in radium. Samples 2, 4, 6, and 7 were taken within or at boundaries of areas mapped as having one or more of the sandy soil types in the vicinity (Dade Fine Sand, Arzell Fine Sand, Rockdale Fine Sand). Sample 8 is also listed as fine sand, but the two samples higher in radium were taken in a ravine and may represent a different soil type or a sediment area. Comparison of samples revealed a close similarity in both radium-226 levels and physical appearance between sample 8A and samples 26C and 47B. The latter are Rockdale soil.

Location 12 is mapped as having the Perrine Marl soil type but is in close proximity to areas mapped as other soil types, including Rockdale. Samples 12A and 12B were taken from different sites within the same slash pine stand. Sample 12B was darker gray than 12A.

A single sample was taken at location 25 and was separated into a rocky portion and a darker-colored, fine soil portion. The rocky portion was significantly lower in radium-226 content.

At location 26, an area mapped as Rockdale soil type, a higher radium-226 content is again associated with a sample which is darker in color. This is also true at locations 27, 33, 36 and 47.

Samples taken at location 42, an area mapped as having the Rockdale soil type, were from natural pine stands and oak hammocks. Sample 42A, the highest in radium-226 content, was collected at a spot in close proximity to three deep, wide solution holes.

Samples having radium-226 contents among the highest encountered in this study were collected at location 43 from the yard of the high radon-222 residence mentioned above. The home is located in an area forested by natural slash pines and has the characteristic reddish-brown Rockdale terra rossa soil prevalent in the area.

Soil profile samples were taken in 15 centimeter increments in a field (location 37) having a 60 cm. Perrine Marl soil covering over the bedrock. The three upper layers of soil had a lower radium-226 content than the bottom layer of soil next to the bedrock. One possible cause considered for elevated radium-226 concentrations was long histories of fertilization with phosphate fertilizers containing radium-226. This field has such a history. The relatively low radium-226 contents found in these samples coupled with the high radium-226 contents found in samples from natural pine stands discredits such a theory.

The radium-226 content of core material from the first 3.6 meters of USGS well G-3315 (location 41) is seen to be low and uniform with depth (Table IV).

Samples 45A and 45B were taken at separate sites within a natural pine forest area while sample 45C was taken in a cultivated avocado grove in close proximity to the pine forest area. The profile samples for location 45 (Table IV) were taken in a nearby tomato field on the property. The surface sample, 45D, has a radium-226 content comparable to that for the nearby natural pine stand while sample 45E, from the bottom of a recently drilled irrigation well, is significantly lower in radium-226.

The mean radium-226 content of rock in contact with the aquifer can be estimated using the measured value of excess radon-222 for the ground water samples and performing a calculation (Eqn. 1) similar to that of Schery (1989).

$$S = (W \times P) / (E \times B) \qquad (1)$$

Here, S is the radon content of the soil, W is the radon content in the ground water, P is the porosity of the rock, E is the emanating fraction or fraction of radon which escapes the rock, and B is the bulk density of the rock. Estimates of the value E are approximately 0.3 (Schery, 1989), porosity varies from 0.45 to 0.60 (Halley and Evans, 1983), and the average bulk density of several samples was determined to be 1320 g/L. Using values that lead to a maximum value of radium-226 resulted in an estimated concentration in the surrounding rock of 0.22 pCi/g. This value compares favorably with the range of measurements (0.17-0.73 pCi/g radium-226) for the USGS well profile and to the radium-226 content of the sample from the irrigation well (sample 45E; 0.83 pCi/g). This suggests that there is no large source of radium-226 at depth, but rather that the enrichment of radium-226 occurs near the surface.

It appears that the high uranium and radium-226 levels found in Dade County are due to natural geologic processes occurring in the area. The concentration of uranium in sea water is 0.002 ppm (McKelvey et al., 1955). Through aprotic processes (e.g., precipitation, evaporation, adsorption), uranium from seawater can be removed from solution. In addition, marine organisms have been found to concentrate uranium in their tissues in varying quantities (Rankama and Sahama, 1950; Mann and Fyfe, 1985). These processes followed by erosion of the more soluble constituents appear to account for the concentration of uranium and radium in the surface soils.

Tatsumoto and Goldberg (1959) reported uranium concentrations ranging from 3.1 to 3.4 ppm for oolite samples taken from the Bahama Banks in a location where a cross-bedded oolitic mound, similar to Florida's Atlantic Coastal Ridge, is evolving (Hoffmeister, 1974). They also found uranium concentrations as high as 5.8 ppm for oolite samples from other locations. In addition, they found uranium concentrations of 2.6 to 4.6 ppm in aragonitic calcium carbonate precipitated from seawater in the laboratory. In a comparison of the uranium concentrations of certain marine calcareous specimens, Tatsumoto and Goldberg reported that the uranium concentration of a bryozoa sample (0.47 ppm) significantly exceeded concentrations of most other marine animals tested (concentrations ranging from 0.004 to 0.21 ppm). Only two species of anthozoa exceeded the bryozoa in uranium concentration (at 2.5 and 3.2 ppm).

In addition to uranium precipitates in the oolitic calcium carbonates of the Atlantic Coastal Ridge, uranium from seawater evaporites may have contributed to the higher concentrations which appear to be located on the western slope of the Atlantic Coastal Ridge. The Everglades forms a natural, somewhat closed basin in which such evaporites could have formed as the sea level slowly dropped.

Chemical weathering proceeds at a relatively fast rate in subtropical climates like that of south Florida. As is evident in the karstic surface of the region, chemical weathering has taken place on the exposed oolite ridge. This weathering process may help explain the enrichment of uranium in the surface soils of the area. The terra rossa soil found along the western slope of the Atlantic Coastal Ridge in south Dade County has been shown to contain a chlorite-like type clay and to have high concentrations of aluminum and iron (Strom and Kim, 1987). Soluble uranium compounds, contained originally in the oolitic limestone, could have been adsorbed by the clay or by hydroxide gels of aluminum and iron and remained with the clay fraction while the more easily dissolved carbonate was eroded away. This would account for the higher than expected radium-226 activity associated with the reddish-brown Rockdale (terra rossa) soil. The Perrine marl may represent the more soluble portion in the weathering process.

In conclusion, it is believed that the elevated levels of uranium and its progeny, radium and radon-222, found in south Dade County, are the result of a combination of natural deposition and surface weathering processes.

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LITERATURE CITED

COHEN, B. L. 1987. Radon. Consumers Union. Mount Vernon, New York. p. 134.

EISENBUD, M. 1987. Environmental Radioactivity. Academic Press. Orlando, Florida. 475 pp.

HALLEY, R. B. AND E. E. EVANS. 1983. The Miami Limestone: A Guide to Selected Outcrops and Their Interpretation. Miami Geological Society. 67 pp.

HOFFMEISTER, J. E. 1974. Land From the Sea, The Geologic Story of South Florida. Univ. Miami Press. Coral Gables, FL. 143 pp.

HUNT, C. B. 1972. Geology of Soils. W.H. Freeman and Company. San Francisco, California. 344 pp.

JENNINGS, L. 1988. High Radon Level found in S. Dade home. South Dade News Leader. Homestead, FL. October 8.

LUCAS, H. F., JR., 1957. Improved low-level alpha scintillation counter for radon. Rev. Sci. Instrum. 28:680-683.

MANN, H. AND W. S. FYFE. 1985. Algal uptake of uranium and some other metals: implications for global geochemical cycling. Precambrian Res. 30:337-349.

McKELVEY, V. E., D. L. EVERHART, AND R. M. GARRELS. 1955. Origin of uranium deposits. Economic Geology. 50th Anniversary Volume:464-533.

NAGDA, N. L., M. D. KOONTZ, R. C. FORTMANN, W. A. SCHOENBORN, AND L. L. MEHEGAN. 1987. Florida Statewide Radiation Study. Florida Institute of Phosphate Research. Bartow, Florida.

PIERCE, W. C. AND E. L. HAENISCH. 1948. Quantitative Analysis, 3rd ed. John Wiley and Sons, Inc. New York. p. 411.

RANKAMA, K. AND T. G. SAHAMA. 1950. Geochemistry. Univ. Chicago Press. Chicago. pp 637-638.

SCHERY, S. D. 1989. Is transpiration an important mechanism for release of ^{222}Rn to the atmosphere? Health Physics 57:1038-1039.

STROM, R. N. AND J. J. KIM. 1987. Genesis of dioctahedral chlorite-like clays in terra rossa soils in South Florida. Florida Scient., 50:253-263.

TATSUMOTO, M. AND E. D. GOLDBERG. 1959. Some aspects of the marine geochemistry of uranium. Geochim. Cosmochim. Acta 17:201-208.

U.S. DEPT. AGRICULTURE. 1958. Soil Survey (detailed reconnaissance) of Dade County, Florida, Series 1947. No.4. 56 pp.

U.S. DEPT. ENERGY. 1981. National Uranium Resource Evaluation: Aerial Gamma Ray and Magnetic Survey, Miami and Key West Quadrangles, Florida. Grand Junction, Colorado.

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FLORIDA PRECIPITATION AND THE PACIFIC EL NINO, 1895-1989

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Abstract: *This study identifies rainfall anomalies, timed with major El Nino events, in seven climatic divisions of Florida. The study also determines the statistical significance of these rainfall anomalies. The seasonal and annual climatology of rainfall is presented for seven climatic divisions of the State for the period 1895 to 1989. Periodogram analysis indicates 5- to 6-year variability in rainfall throughout most of Florida, in particular during winter and spring. Super-posed epoch analysis, utilizing only rainfall during the year prior to and concurrent with a major El Nino, shows that State-wide rainfall anomalies are timed with these Pacific events. The most significant anomalies are: (1) below normal rainfall over all of the State during winter and spring the year prior to an El Nino; and (2) above normal rainfall over all of the State during winter and spring the second year of an El Nino. Largest rainfall anomalies have occurred in the southern climatic divisions of Florida. During winters of the second year of El Nino, south Florida rainfall anomalies range from +76 to +94mm (+3.0 to +3.7inches) depending on the climatic division. These anomalies are 45 to 66 percent above normal winter rainfall, and are significant at the 0.999 level.*

The drought that south Florida experienced during the winter of 1990 began in late 1988 and is the most extreme low-rainfall condition since 1971. Historically, Florida has experienced many previous droughts, as illustrated in Fig. 1. This curve shows 12-month average rainfall for Florida's "Lower East Coast" during the past century. Since the late 1930s, there have been a minimum of five low-rainfall conditions of about the same severity as the present condition. From 1895 to the 1930s, low-rainfall events also occurred. However, they appear to have been less severe than in recent times.

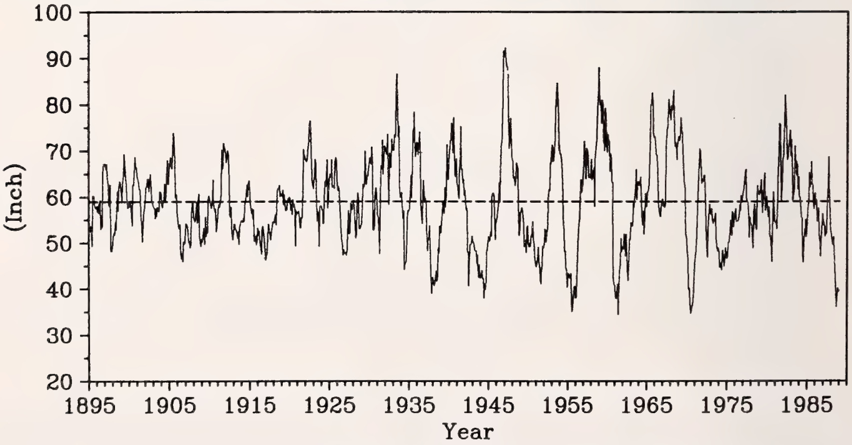

Fig. 1. Twelve-month total rainfall for the Florida Lower East Coast division for the period 1895 to 1989. Rainfall totals are running averages, and are plotted at the first month of the 12-month period.

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There have also been periods of greater-than-normal rainfall during this time. The last period of excess rainfall was in 1982-83. This was also the time of the last major "El Nino," a name sometimes associated with warming of large equatorial regions of the Pacific, but more correctly associated with warming of ocean waters along the northwest coast of South America (Quinn et al., 1987).

We are not the first to note that Florida precipitation anomalies and El Nino have occurred concurrently. It is well known that weather and climate in many regions of the world are modified during El Nino (Ropelewski and Halpert, 1986, 1987). This does not imply that El Nino is the cause of the many regional anomalies in weather and climate around the earth, but rather that El Nino is just one of many regional anomalies associated with globally occurring changes in atmospheric and oceanic circulations at these times.

The Present Study expands on previous work identifying El Nino-timed rainfall anomalies for regional areas of Florida, and it calculates the statistical significance of these results. As will be shown, highly significant relationships exist between the timing of El Nino events and rainfall anomalies in Florida.

We used the Climatic Division (CD) precipitation data, a data set prepared and maintained by the National Climatic Data Center (NCDC, 1989) of the National Oceanic and Atmospheric Administration. The data set is composed of monthly precipitation totals for the period January, 1895 to December, 1989 (95 years) for each of the seven climatic divisions of Florida. The divisions are identified in Fig. 2.

The CD data set is based on rainfall information obtained at first-and second-order weather stations as well as at cooperative stations in the State. Individual station data are spatially weighted to form means of monthly precipitation for each of the seven climatic divisions (Karl et al., 1984).

METHODS—*Florida Precipitation Climatology*—The monthly CD rainfall information was used to form seasonal and annual precipitation totals for each of the climatic divisions. Seasons were defined as: "Winter": December, January and February; "Spring": March, April and May; etc.

Climatological average rainfall amounts were determined for the seasons and the year, based on the complete 95 year record. Arbitrarily, we used these 95-year averages as "normals" in the study. Normals are given in Table 1. Rainfall units are: millimeters per season or year, and inches per season or year. Asterisks have been added to Table 1 to identify extremes of the normal rainfall. Both extremes occurred in the "Everglades and SW Coast" division. The smallest normal rainfall occurred during winter, 134mm (5.3 inches); and the largest during summer, 600mm (23.6 inches) in that division.

Normal rainfall in northern Florida exceeded that in southern Florida during the winter and spring; whereas, normal rainfall in southern Florida exceeded that in the north during the fall (Table 1).

For the year as a whole, normal rainfall was largest in northern Florida, and smallest in the "Keys", as is evident (Fig. 3 circled values). An exception to this otherwise general rule was the normal rainfall in the "Lower East Coast" division which totaled 1490mm (58.7 inches), clearly exceeding rainfall in adjacent divisions. Also, the "Everglades and SW Coast" division had somewhat enhanced rainfall in comparison with that of the "South Central" and "Keys" divisions.

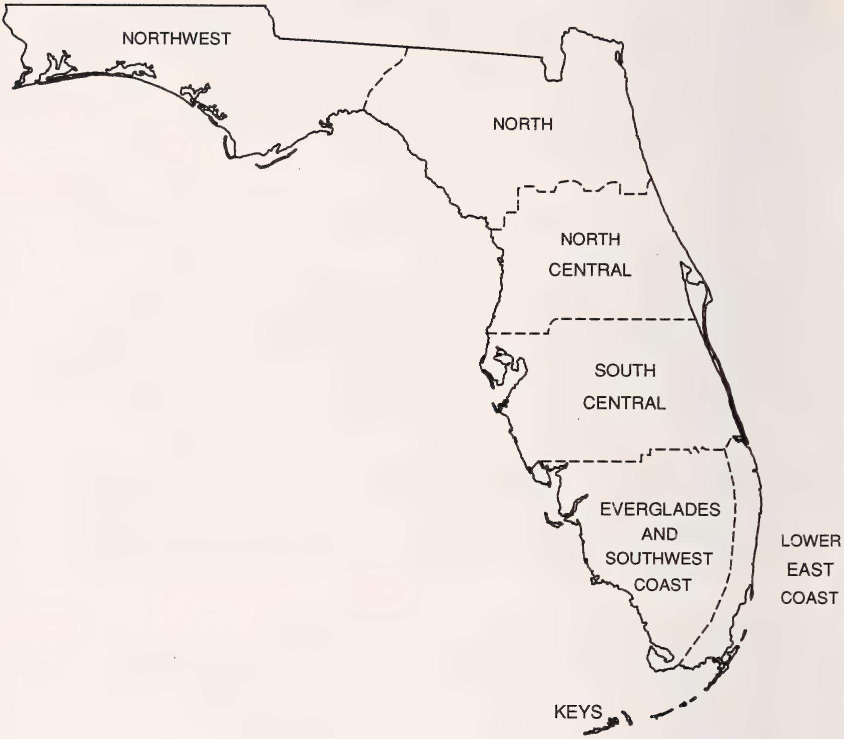

FIG. 2. The seven climatic divisions of Florida, as defined for the climatic division (CD) rainfall data (NCDC, 1989) used in this investigation.

TABLE 1. Climatological average rainfall for the period 1895 to 1989 for the seven climatic divisions of Florida. Asterisks indicate the highest and lowest values for the State. Rainfall totals are given in millimeters (inches in parenthesis).

	Season				
Division	Winter	Spring	Summer	Fall	Annual
Northwest	336	333	505	307	1481
	(13.2)	(13.1)	(19.9)	(12.1)	(58.3)
North	253	260	538	303	1354
	(10.0)	(10.2)	(21.2)	(11.9)	(53.3)
North Central	199	249	561	314	1324
	(7.8)	(9.8)	(22.1)	(12.4)	(52.1)
South Central	178	238	568	322	1307
	(7.1)	(9.4)	(22.4)	(12.7)	(51.5)
Everglades & Southwest coast	134**	235	600**	341	1311
	(5.3)	(9.3)	(23.6)	(13.4)	(51.6)
Lower East Coast	168	299	540	483	1490
west coast	(6.6)	(11.8)	(21.3)	(19.0)	(58.7)
Keys	143	186	366	384	1079
	(5.6)	(7.3)	(14.4)	(15.1)	(42.5)

From these normals, we calculated the seasonal fractions of annual rainfall for each of the seven divisions. The results are given (Fig. 3). Compared with other seasons, winter rainfall was the smallest fraction (0.1 to 0.2) throughout all of Florida, except for the "Northwest" division where fall rainfall was the smallest fraction (0.21). Similarly, summer rainfall was the largest fraction (0.34-0.46) over all of the state, except for the "Keys" where fall rainfall was the largest fraction (0.36). Clearly, winter and spring were the dry seasons, and summer and fall the wet seasons in the state.

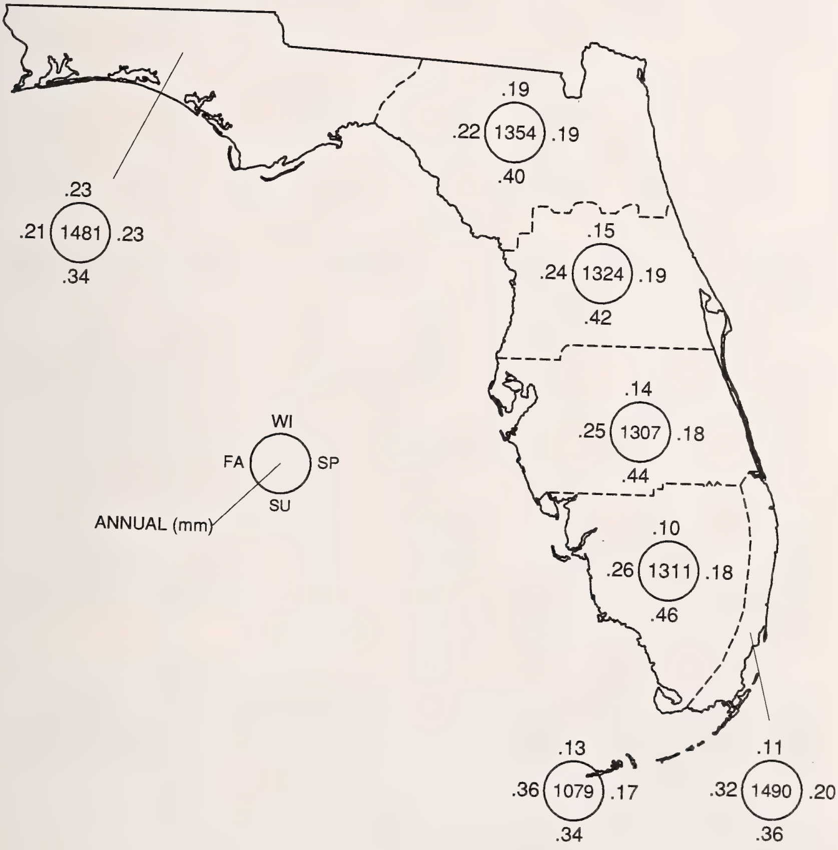

FIG. 3. Climatological average annual rainfall in millimeters (circled values) and seasonal fraction of annual rainfall for the seven climatic divisions of the state.

RESULTS—*Anomalous Florida Rainfall During El Nino*—The long history of El Nino, dating back four and a half centuries, suggests that although these events are not truly periodic in occurrence, the most frequently occurring times between major events is six and seven years (Hanson et al., 1989). A few major events have recurred in four and five years, although this was rare. The (arithmetic) average of the recurrence times was 9.9 years; and the longest recurrence times between major events were 14 and 20 years. The last strong event began 8 years ago in 1982 (Quinn et al., 1987).

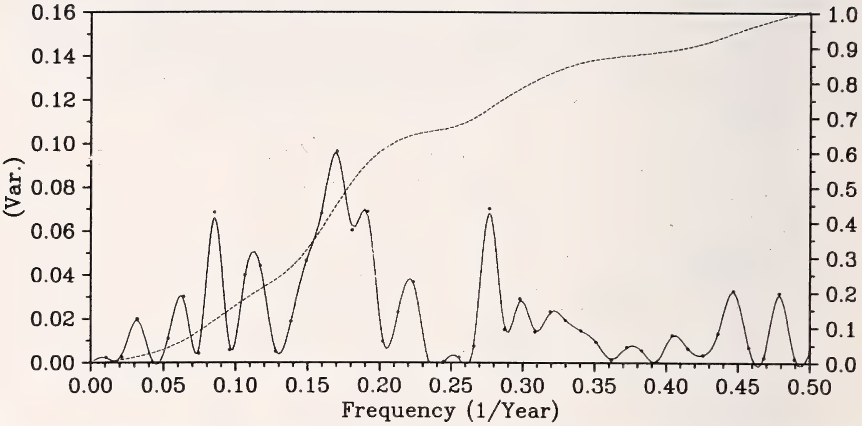

FIG. 4. Periodogram analysis of annual rainfall for Florida's Lower East Coast division, based on data from 1895 to 1989. Rainfall variance is given by the solid line, and summation of variance is illustrated by the dashed line.

We examined the frequency domain of seasonal and annual precipitation for each of the seven climatic divisions. In Fig. 4, for example, rainfall variance is indicated for the 47 harmonics of the 95-year time series for the "Lower East Coast." The summation of variance (Fig. 4 dash line) is also shown to range from zero to unity. The most significant feature is the broad peak at 0.15-0.19 cycles per year, or at periods of 6.3, 5.9, 5.5, and 5.2 years. This broad peak contains about 30 percent of the total variance, and we note that more than 50 percent of the total variance occurs at periods of greater than 5 years. These periods of 6.3-5.2 years are similar to the most frequently occurring recurrence times of El Nino noted above.

Table 2 summarizes the variance of seasonal rainfall as a function of period for each of the seven climatic divisions. The variance at these important interannual periods is greatest in the "North Central," "South Central" and "Lower East Coast" divisions during winter. The variance is less in spring and appears to be near zero during summer and fall.

Analysis of the frequency domain utilized all of the 95-year rainfall records of the climatic divisions. However, to study rainfall variability associated with El Nino events, we made use of a more direct method of analysis, based primarily on the times of El Nino.

Superposed Epoch Analysis—This method examined Florida rainfall for the year prior to and the years of El Nino. The method is summarized here, and is discussed in detail in Panofsky and Brier (1965).

In our analysis we have used only classes of El Nino events that were strong enough to persist for two successive years. We established the criteria that only "moderate" and "strong" events (as defined by Quinn and co-workers, 1987) be used in the study. Additionally, we included the requirement that the year prior to the two-year event must be a non-El Nino year.

The following nine two-year events meet these criteria: 1899-00, 1911-12, 1917-18, 1925-26, 1930-31, 1939-40, 1957-58, 1972-73, 1982-83.

TABLE 2. Sections of periodogram analyses of annual rainfall for Florida climatic divisions and for periods 5.2-6.3 years. Table values are fraction of total variance (max. = 1.0). Blank values indicate the fraction of variance is <0.05.

Division No.	Period (Years)	Annual	Seasons			
			Winter	Spring	Summer	Fall
	6.3	—	—	—	—	—
1 NW	5.9	.083	.079	.054	.057	—
	5.5	—	—	—	—	.069
	5.2	—	—	—	—	—
	6.3	—	—	—	—	—
2 N	5.9	.064	.101	.079	—	—
	5.5	—	.059	—	—	—
	5.2	—	—	—	—	—
	6.3	—	.098	—	—	—
3 N Cntr.	5.9	.086	.078	.139	—	—
	5.5	—	.077	—	—	—
	5.2	—	—	—	—	—
	6.3	—	—	—	—	—
4 S Cntr.	5.9	.070	.090	.095	—	—
	5.5	—	.099	—	—	—
	5.2	—	.095	—	—	—
	6.3	—	—	—	—	.063
5 Ev. & SW	5.9	.095	—	.088	—	—
	5.5	.059	.092	—	—	—
	5.2	—	.116	—	—	—
	6.3	.068	—	—	—	.101
6 Lwr. E Coast	5.9	.096	.068	.076	—	—
	5.5	.060	.065	—	—	.068
	5.2	.069	.086	.051	—	—
	6.3	—	—	—	—	—
7 Keys	5.9	.090	.072	.111	.081	—
	5.5	.064	—	—	—	—
	5.2	—	.130	—	—	—

The relationship between a continuous variable and an event related variable is often studied by the "superposed epoch" method (Panofsky and Brier, 1965). This method is especially useful for analysis related to discrete events, such as El Nino events. In this analysis, "key" dates are identified in the record, and the continuous variable is sorted on times relative to these "key" dates.

In our application, we selected winter of the year prior to the two-year event as the "key" season. Then for each of the nine events, we sorted the rainfall data for the "key" season and the following 11 seasons into 12 "composite" seasons. The three years of the 12 composite seasons are termed "prior years," "event first year," and "event second year."

Rainfall averages were calculated for each of the 12 composite seasons and are listed in Table 3. They are given as anomalies, or departures from the long-term normal. The results show alternating periods of below and above normal rainfall for Florida over the 12 composite seasons.

TABLE 3. Composite seasonal rainfall anomaly (departure from normal) for the seven climatic divisions of Florida, based on nine two-year El Ninos during the period 1895-1989. A Monte Carlo method (see text) was used to estimate the statistical confidence limits, noted by asterisks. The table values are seasonal rainfall anomalies in millimeters.

					El Nino Year							
Climatic Division	Year Prior				First Year				Second Year			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
1. Northwest	−82#	−81#	+7	−4	−10	−43*	−26	+32	+33*	+77*	−4	+3
2. North	−70*	−63#	+28	+32	−16	−6	−9	−17	+28	+72*	−32	−51*
3. North Central	−57*	−67#	−2	+30	−16	+29	+22	−36*	+40	+59#	−46	−27*
4. South Central	−54*	−76#	−5	+32	−19	+41	+33*	−34*	+67*	+56#	−43	−18
5. Everglades SW Coast	−43#	−75#	−12	−3	−18	+38*	+35*	−29*	+81#	+45*	−27	−14
6. Lower East Coast	−42*	−99#	−50	−33*	−7	+54*	+31	−53*	+76#	+42*	−21	+6
7. Keys	−48*	−61*	−38	+28	−13	+40*	+22	−36*	+94#	+32*	−8	−34*

*—significance 0.900 or better
#—significance 0.999 or better

Also calculated with the superposed epoch method, was the ratio of the number of cases of rainfall greater than normal to the number of cases less than normal. In total there are nine cases for each composite season. Thus, the ratio extremes are 0/9 and 9/0. The results are listed (Table 4).

Monte Carlo Significance Estimate—To obtain an estimate of whether rainfall anomalies of Table 3 may be chance occurrence or statistically unusual, we utilized a Monte Carlo method of testing similar to the "bootstrap method" of Efron (1982). The method simulates an 1895-1989 El Nino time series from the original chronology. The procedure requires that the true intervals between El Nino events be applied in constructing each random simulation. This requirement has the advantage of preserving (in each simulated time series) the natural low-frequency variability of the true El Nino chronology. Using this procedure 1000 El Nino chronologies were simulated.

TABLE 4. This table is similar to table 3 except indicated values are the ratio of the number of cases of rainfall >normal to the number of cases <normal. The total number of cases is nine, one for each of the nine double year El Ninos that have occurred during the period 1895-1989. Dashes indicate 4/5 and 5/4 values of no significance.

					El Nino Year							
Climatic Division	Year Prior				First Year				Second Year			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
1. Northwest	1/8	2/7	3/6	—	—	3/6	2/7	—	—	—	—	—
2. North	0/9	2/7	—	6/3	—	—	3/6	3/6	6/3	6/3	—	—
3. North Central	2/7	2/7	—	6/3	—	—	6/3	2/7	7/2	8/1	2/7	—
4. South Central	1/8	1/8	—	7/2	3/6	—	6/3	3/6	8/1	8/1	2/7	—
5. Everglades SW Coast	1/8	1/8	—	—	3/6	—	—	3/6	8/1	6/3	3/6	—
6. Lower East Coast	0/9	0/9	3/6	—	—	6/3	6/3	2/7	7/2	6/3	—	—
7. Keys	1/8	2/7	—	6/3	3/6	6/3	—	2/7	7/2	7/2	—	3/6

Rainfall data were sorted for each of the 1000 simulations in the same manner as described for sorting based on the El Nino chronology. This provided 1000 estimates of rainfall anomalies for each season and each climatic division. The frequency of occurrence distribution of the 1000 rainfall anomalies was used to estimate rainfall confidence limits of 90, 95, 99, and 99.9 percent for each season and each climatic division. In this procedure, for the 95 percent confidence interval, for example, 25 of the 1000 simulated rainfall values were less than the lower confidence limit, and 25 exceeded the upper confidence limit.

An example of rainfall at various confidence limits for the "Everglades and SW Coast" division is given (Table 5). In addition, the significance of the rainfall anomalies of Table 3 is indicated by identifying, with asterisk, those anomalies that exceed the 90 and 99.9 percent confidence levels.

TABLE 5. An example of Monte Carlo based estimates of confidence intervals in seasonal rainfall for the Everglades and SW Coast division for the four seasons. Estimates are based on 1000 Monte Carlo simulations of the 95 year El Nino time series (see text). Units are millimeters.

	Confidence Limits:							
	Lower				Upper			
	0.90	0.95	0.99	0.999	0.90	0.95	0.99	0.999
Winter	−25	−29	−35	−43	+34	+42	+51	+58
Spring	−33	−41	−59	−62	+37	+45	+63	+68
Summer	−58	−65	−78	−82	+31	+36	+52	+57
Fall	−16	−23	−34	−42	+64	+77	+87	+99

DISCUSSION—The composite rainfall averages and the composite ratios give indications of the sign and size of the rainfall anomaly by season for the three-year (El Nino) period. For example, during winter of the year prior to El Nino, rainfall for the "lower East Coast" division averaged 42mm below normal (Table 3). Also, for that division and for all nine El Nino occurrences, rainfall averaged below normal (Table 4) during winter of the year prior to El Nino.

Rainfall average and ratio values (Tables 3, 4) suggest that during winter and spring of the year prior to El Nino rainfall is below normal for all climatic divisions of the State. Results are inconclusive for rainfall anomalies during summer and fall of the prior year.

These statistics also suggest that during the first year of El Nino, rainfall is: above normal in south Florida during spring; above normal in central Florida during summer; and below normal over all of the State, except in the extreme north, during fall.

The strongest rainfall signal appeared to be during the second year of the event. In that year rainfall anomalies ranged from 28-94mm above normal during winter and spring over all climatic divisions, and tend to be small and relatively inconsistent in sign during summer and fall.

We calculated the El Nino-related rainfall anomaly as a fraction of normal rainfall. The maximum and minimum of seven climatic division anomalies are given (Fig. 5). For this 12-season period before and during El Nino, the most extreme anomalies occurred in the "Keys" and "Everglades and SW Coast" divisions. There, rainfall during winter and spring of the year prior to the event was 32-34 percent below normal, and during the second winter of the event was more than 60-66 percent above normal.

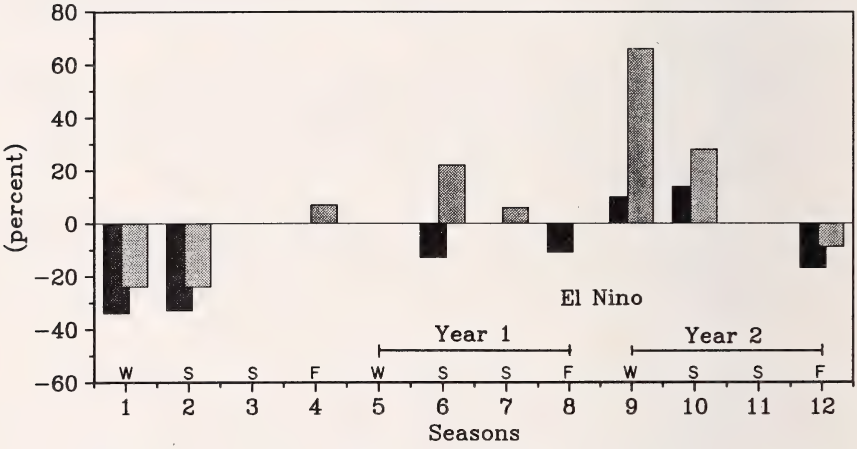

Fig. 5. The bar pairs indicate the RANGE of rainfall anomalies among the seven anomalies of the climatic divisions of Florida. Values are given for 12 consecutive seasons relative to El Nino occurrence. The bar pairs are based on precipitation during nine two-year El Ninos during the period 1895 to 1989. Only rainfall anomalies with confidence limits of 0.90 or greater are shown. The rainfall anomalies illustrated are percent of normal rainfall for the given climatic division.

LITERATURE CITED

Efron, B. 1982. The Jackknife, the Bootstrap and Other Resampling Plans. Arrowsmith, Bristol, England, 92pp.

Hanson, K., G. W. Brier, and G. A. Maul. 1989. Evidence of significant nonrandom behavior in the recurrence of strong El Nino between 1525 and 1988. Geophy. Res. Lett. 16:10:1181-1184.

Karl, T. R., R. E. Livezey, and E. S. Epstein. 1984. Recent unusual mean temperatures across the contiguous United States. Bull. Amer. Meteor. Soc. 65:1302-1309.

National Climatic Data Center (Ncdc). 1989. Climatic Division Precipitation Data. NOAA. Federal Building. Asheville, NC 28801-2696.

Panofsky, H. A., and G. W. Brier. 1965. Some Applications of Statistics to Meteorology. Penn. State Univer. Press. University Park, PA p. 159.

Quinn, W. H., V. T. Neal, and S. E. Antunez de Moyolo. 1987. El Nino occurrences over the past four and a half centuries. J. Geophy. Res. 92:C13:14449-14461.

Ropelewski, C. F. and M. S. Halpert. 1986. North American precipitation and temperature patterns associated with the El Nino/southern oscillation (ENSO). Mon. Wea. Rev. 114:2352-2362.

________ and M. S. Halpert. 1987. Global and regional scale precipitation patterns associated with the El Nino/southern oscillation. Mon. Wea. Rev. 115:1606-1626.

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ALGAE FROM LIMED AND UNLIMED SOILS IN NORTH-CENTRAL FLORIDA

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ABSTRACT: *Edaphic algae were identified from five soil samples collected at one time from untreated acid sands and from slightly acid sands that had been limed and fertilized. The study methodology, which included culturing and close observations of each isolated species, yielded 17 green algae, 5 blue-green algae, 5 diatoms, and 1 green euglenoid. Numbers of taxa found in the limed and fertilized plots were similar to those found in the untreated soils.*

SOIL plots established in 1961 to study effects of combined nitrogen and lime on Pensacola bahiagrass (*Paspalum notatum* Flügge) provided an opportunity to compare taxa of soil algae from treated and non-treated soils. Studies on soil algae of north-central Florida have been concerned mainly with the occurrence of edaphic algae in relation to soil type and pH (Norton and Davis, 1975; Smith, 1944; Smith and Ellis, 1943). However, except for the work of Norton and Davis (1975), all previous reports used identification schemes and methodology no longer employed (Ruble, 1983). This paper provides a record of a past condition essential to several ongoing and future research projects at the study site.

MATERIALS AND METHODS—Soil plots located on the Beef Research Institute of the University of Florida, Alachua County, in north-central Florida provided soil samples for this study. Soil in this area has been designated Leon Fine Sand (Taylor et al., 1954). The water table was within 5 cm of the soil surface of the study area.

Five soil samples were collected on April 1971, from plots that had received low lime levels (4.48 tons/ha), and high lime levels (17.92 tons/ha) but no combined nitrogen. The low lime level (L_1) was obtained by applying Ocala lime (92% $CaCO_3$), and the high lime level (L_5) by marble chips (99% $CaCO_3$). Other fertilizers applied to the limed plots included phosphorus at 4.4 kg/ha, potassium at 47 kg/ha, $MgSO_4$ at 224 kg/ha, and fritted micronutrients (FTE 503, Ferro Corporation, Cleveland, Ohio) at 30 kg/ha. All nutrients were thoroughly mixed into the soil at the time of application. Untreated areas from which soil was collected included an untreated plot (U), as well as the east (EB) and north borders (NB) of other plots that had received no nutrients. Treated areas from which soil was collected included a low lime level (L_1) plot and a high level (L_5) plot. Samples were gathered with a sterile 50 mm stainless steel cork borer wiped clean and re-sterilized with 95% ethanol after each insertion into the soil. The upper 3 cm of several plugs from each plot were combined to give a composite sample. These samples were placed into sterile plastic bags and transported to the laboratory. The pH was determined from a 2:1 soil and distilled water mixture with a combination glass electrode.

To isolate taxa, a 10-g composite sample (fresh weight) from each collection site was placed into three sterilized 125-ml Erlenmeyer flasks, each with a different sterile liquid. One flask contained 70 ml of Bold's Basal medium (Bold and Parker 1962) modified by adding a 2.8 mg/l $NaSiO_3$ to aid diatom growth; another flask, 70 ml of modified Bold's Basal medium (BBM) without combined nitrogen; and the third flask, 70 ml of glass distilled water. The flasks were capped with aluminum foil. The flasks with distilled water were shaken vigorously for 6 weeks on a mechanical device. Concomitantly with the above methods, 10 g of soil from each sample was placed on sterile filter paper kept moistened with BBM in sterile petri plates.

All cultures were placed in an environmental chamber with fluorescent and incandescent light, at an intensity of approximately 1000 Ft.-C on a 18-6 hr. light-dark cycle. The temperature was maintained at 26 ± 1 °C.

Samples were removed every 4-6 days for 6 weeks from the liquid cultures and then placed on agar-solidified, sterile BBM. As algae appeared in these cultures and in the filter paper cultures, unicellular and filamentous forms were isolated by direct picking under a binocular microscope and then transferred into petri dishes containing solidified BBM. The organisms that grew were repeatedly streaked and transferred on the surface of BBM agar until unialgal cultures were obtained. The strains were then placed into test tubes containing either liquid or solidified BBM for subsequent study. All blue-green algae isolates were also placed in petri plates containing BBM without combined nitrogen.

Blue-green algae were identified with the use of keys in Cocke (1967) and Desikachary (1959). Coccoid green algae were identified by using life history characteristics revealed as each taxon passed through its life cycle several times. The criteria of Starr (1955), Archibald and Bold (1970), and Bold (1970) for distinguishing among the zoospore-producing coccoid species, and the supplementary characteristics of Bold and Parker (1962) for using shape and color of cell masses, were used to determine species.

TABLE 1. Soil algae isolated from five plots. U = uncultivated soil, NB = north border, EB = east border, L_1 = liming level one, L_5 = liming level five.

Taxa	U	NB	EB	L_1	L_5
GREEN ALGAE					
Chlorella vulgaris Beijerinck	+	+	+	+	+
Chlorococcum pulchrum Archibald & Bold	+	+			
Chlorococcum macrostigmatum Starr					+
Chlorococcum vacuolatum Starr					+
Chlorococcum rugosum Archibald & Bold		+			
Chlorococcum novae angliae Archibald & Bold	+	+	+	+	+
Cosmarium lunatum W. & G. S. West		+			
Cylindrocystis brebissonii Menegh.	+	+	+	+	+
Euastrum sp.		+		+	
Hormidium sp.		+		+	
Microspora wittrockii (Wille) Lager.	+				+
Nannochloris bacillaris Naumann	+	+	+	+	+
Schizomeris leibleinii Kütz.					+
Stichococcus bacillaris Näg.		+	+	+	+
Trentepohlia aurea (L.) Mart.	+				
Ulothrix subtilissima Rab.			+		+
EUGLENOIDS					
Euglena sp.	+	+	+	+	+
DIATOMS					
Cocconeis placentula Ehr.	+			+	
Navicula mutica Kütz.				+	
Nitzschia palea (Kütz.) W. Sm.				+	
Pinnularia borealis Ehr.	+	+	+	+	+
Pinnularia subcapitata Greg.			+	+	
BLUE-GREEN ALGAE					
Anabaena sp.	+	+	+	+	+
Anacystis montana (Näg.) Dr.		+			
Aphanothece sp.			+	+	+
Cylindrospermum minutum Wood		+	+		
Fischerella ambigua (Näg.) Gom.			+	+	
Lyngbya putealis Mont.			+		+
Nostoc muscorum Ag.	+	+	+	+	+
Oscillatoria submembranacea Ard. & Straff.		+	+	+	+
Stigonema mesentericum Geitler		+			
TOTALS	12	18	18	17	18

Diatoms were cleaned and prepared for identification with Swift's (1967) method. The cleaned frustules were mounted in Permount and examined with a phase contrast microscope at 1000X magnification. An I_2-KI solution was used to test other algae for starch, to determine pyrenoid presence and number, and to clarify nuclei. Identification of sheath material on cell walls was facilitated by a 5% methylene-blue stain.

RESULTS—Of the 31 taxa isolated and identified in this study, 16 were green algae, 5 were diatoms, 9 were blue-green algae, and 1 a green euglenoid (Table 1). *Chlorella, Chlorococcum, Cylindrocystis, Nannochloris, Euglena, Pinnularia, Anabaena* and *Nostoc* occurred in every sample. The number of taxa from the nontreated plots included 12 from the uncultivated area, 18 from the north border area, and 17 from the east border area. The number of taxa in the treated plots included 17 from liming level L_1 and 18 from liming level L_5. The uncultivated, untreated sample (U) registered a pH of 5.4, the north border pH 5.8, the east border pH 5.5, liming level one pH 6.4, and liming level five pH 6.1. *Anabaena* sp., *Cylindrospermum minutum,* and *Nostoc muscorum* grew well after repeated transfers on BBM without combined nitrogen. Blue-green algae first appeared in cultures from liming level L_5.

DISCUSSION—Although most blue-green algae prefer neutral to alkaline environments (Holm-Hansen 1968), this study, as well as those of Norton and Davis (1975), and Arvic (1971) indicate that a number of species also may occur in acid conditions. Indeed, the numbers of taxa isolated from the unlimed soils were similar to those of the limed soils. Growth of *Anabaena, Cylindrospermum,* and *Nostoc* on media without combined nitrogen suggests these organisms can fix atmospheric nitrogen.

Except for one untreated plot (U) which yielded only 12 taxa, the remaining untreated plots (NB and EB), and the treated plots (L_1 and L_2) produced about 18 species. For most plots, fertilization and liming had little effect on the occurrence of taxa.

LITERATURE CITED

ARCHIBALD, P. A. AND H. C. BOLD. 1970. Phycological Studies XI. The genus *Chlorococcum* Meneghini. Univ. of Texas Publ. 7015, Austin, Texas.

ARVIK, J. H. 1971. Soil algae of northwest Florida. Quart. J. Florida Acad. Sci. 33:247-252.

BOLD, H. C. 1970. Some aspects of the taxonomy of soil algae. Ann. N.Y. Academy Sci. 175:601-616.

_________ AND B. C. PARKER. 1962. Some supplementary attributes in classification of *Chlorococcum* species. Arch. Microbiol. 42:267-288.

COCKE, E. C. 1967. The Myxophyceae of North Carolina. Published by the author, 206 pp.

DESIKACHARY, T. V. 1959. Cyanophyta. Indian Council of Agricultural Research, New Delhi, 686 pp.

HOLM-HANSEN, O. 1968. Ecology, physiology and biochemistry of blue-green algae. Ann. Rev. Microbiol. 22:47-70.

NORTON, J. R. AND J. S. DAVIS. 1975. Soil algae from north central Florida. Quart. J. Florida Acad. Sci. 38:77-81.

RUBLE, R. W. 1983. Soil algae from the Homestead, Florida, winter vegetable growing area. M.S. thesis, University of Florida, Gainesville, Florida.

SMITH, F. B. 1944. The occurrence and distribution of algae in soils. Quart. J. Florida Acad. Sci. 7:44-49.

_________ AND H. R. ELLIS. 1943. Preliminary report on the algal flora of some Florida soils. Quart. J. Florida Acad. Sci. 6:59-65.

STARR, R. C. 1955. A comparative study of *Chlorococcum* Meneghini and other spherical, zoospore-producing genera of the Chlorococcales. Science Series No. 20, Indiana Univ. Press, Bloomington, Indianna.

SWIFT, E. 1967. Cleaning diatom frustules with ultraviolet radiation and peroxide. Phycologia 6:161-163.

TAYLOR, A. E., R. G. LEIGHTY, M. B. MARCO, C. LOUNSBURY, J. R. HENDERSON, AND O. E. GALL. 1954. Soil Survey of Alachua County, Florida. Series 1940, No. 10, United States Department of Agriculture in coöperation with the University of Florida Agricultural Experiment Station, 66 pp.

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HYPOXIA-INDUCED CHANGES IN VERTICAL POSITION AND ACTIVITY IN JUVENILE SNOOK, *CENTROPOMUS UNDECIMALIS*: ITS POTENTIAL ROLE IN SURVIVAL

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Abstract: *An* in situ *survival test of fishes using hypoxic impounded mangrove swamps indicated that some fishes change vertical position within the water column when compared to observations under more oxygenated conditions. These observations led us to experimentally examine changes in vertical position and activity under hypoxic conditions in juvenile snook, Centropomus undecimalis, which are indigenous to mangrove swamp habitats. These experimental data support our* in situ *data and indicate that juvenile snook move towards the oxygenated surface waters and decrease activity there when deeper waters are anoxic.*

Mangrove forests bordering coastal areas of South Florida are important habitats for fishes (Thayer et al., 1987), even though mangroves experience periods of low oxygen and high hydrogen sulfide (H_2S) concentrations (Tabb et al., 1974; Abel et al., 1987; Taylor, 1988; Chew et al., 1990). However, a large percentage of this critical habitat has been impounded for mosquito control (Gilmore, 1987) further increasing the frequency and duration of decreased oxygen and increased H_2S periods. During the warm-wet season, impoundments are closed from the surrounding estuary and these habitats often become hypoxic, resulting in periodic fish kills. Fishes utilizing these habitats must use physiological (Hochachka and Somero, 1984) and/or behavioral (Saint-Paul, 1984; Kramer, 1987) mechanisms to survive periods of low oxygen.

During a field test which simulated an hypoxic event, we documented mortality of a number of transient fish species, most notably snook *(Centropomus undecimalis)*, ladyfish *(Elops saurus)*, striped mullet *(Mugil cephalus)*, and black drum *(Pogonias cromis)*. During this event, we noticed snook and mullet had oriented near the air-water interface. This behavior is identical to that described for small, dorsally flattened fishes and is called aquatic surface respiration (ASR: Lewis, 1970). This behavior allows fish to utilize the well oxygenated surface film at the air-water interface during hypoxic or anoxic events. Based upon these observations and data on snook respiratory metabolism in hypoxic media (Peterson and Gilmore, 1991), we hypothesized that snook would use behavioral as well as physiological mechanisms to deal with hypoxic conditions. We predicted that snook would move toward the surface in hypoxic conditions when compared with normoxic conditions. Herein, we document both vertical distributional changes and activity due to oxygen level in juvenile snook *(Centropomus undecimalis)*.

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MATERIALS AND METHODS—Fish were collected from impounded mangrove swamps and maintained in the laboratory as described in Peterson and Gilmore (1988). In the laboratory, fish were maintained in 76-L aquaria at 30°C and 30 o/oo salinity under a 12L:12D photoperiod, centered at 1230 for 8 days prior to testing. Experimental units were 38-L aquaria that were held at the same temperature, salinity and photoperiod as the holding aquaria. Each unit contained only a heater and aerator and was separated from other units by opaque partitions. A horizontal grid along the back of each unit (with 2 cm increments, except the bottom line which was 3 cm) was used to document vertical position of individual fish. Maximum water depth was 23 cm. One fish, ranging in size from 75-99 mm standard length (SL) (5.3-11.9 g wet weight/WW), was transferred to each of five experimental units, about 15 h prior to the experimental run. The next day, the aerator and heater were removed fifteen minutes prior to the experiment. At 0800 h, we recorded vertical movement for 46 min under normoxic (169.2 ± 4.4 mm Hg) conditions with a Sony Handycam (Model: CCD-M8U) camcorder. Then, we reduced the oxygen tension of each unit to 38.5 ± 1.3 mm Hg (hypoxic) over a 3-h period by bubbling nitrogen through an air-stone. The fish were allowed 2.5 h to adjust to this new oxygen tension, and then movements were recorded as described above for an additional 46 min.

Experimental Po_2 tensions were measured on a calibrated Radiometer PHM-73/D616/E5046 oxygen analyzer system. Five individuals were used and each was used only once. The position of each fish (distance from the bottom, cm) was measured every minute from the video tape. Variation in movement was documented by enumerating the total number of horizontal lines crossed by each individual over the 45 minute time period. The individual positions were then partitioned into three equal-sized vertical layers: bottom (0-7 cm), middle (8-15 cm) and top (16-23 cm). The amount of time spent in each layer (presented as the % of total time) was determined. We did not include the first minute of behavior in any analysis due to possible disturbance from the observer leaving the room. Because these are paired observations, we compared rankings of the entire data set by a Wilcoxin matched-pairs signed-ranks test ($P < 0.05$). All values are reported as $\bar{X} \pm 1$ SD unless indicated.

TABLE 1. Measurements of individual (%: movement over a 45 minute period) and overall (%: grand mean of mean individual movement) coefficient of variation by treatment.

Normoxia		Hypoxia	
1*	90.3	1*	51.1
2	30.0	2	64.8
3	115.7	3	45.9
4	74.1	4	47.4
5	86.8	5	112.9
Mean	79.4	Mean	64.4

* = individual number

RESULTS—There was no marked difference in Po_2 tension throughout the aquaria or over the 2.5-h adjustment period. Overall activity in hypoxic media was reduced by 15% (Table 1). Additionally, there was considerable individual variation in vertical distance off the bottom over the 45 minutes and between oxygen tensions (Table 1). Linear regression analysis of time as a function of vertical distance from the bottom of the aquaria indicated no significant relationship (Fig. 1). Individuals 1, 3, and 4 shifted position towards the top and spent more time there than in the other two levels (Table 2). However, individual 2 did not shift markedly upward and spent about the same amount of time near the top and bottom while individual 5 spent most of its time near the bottom (Table 2). There was no significant difference in mean distance off the bottom between normoxic and hypoxic conditions (Mean = 4.5 cm; $Z = -0.94$, $P > 0.05$).

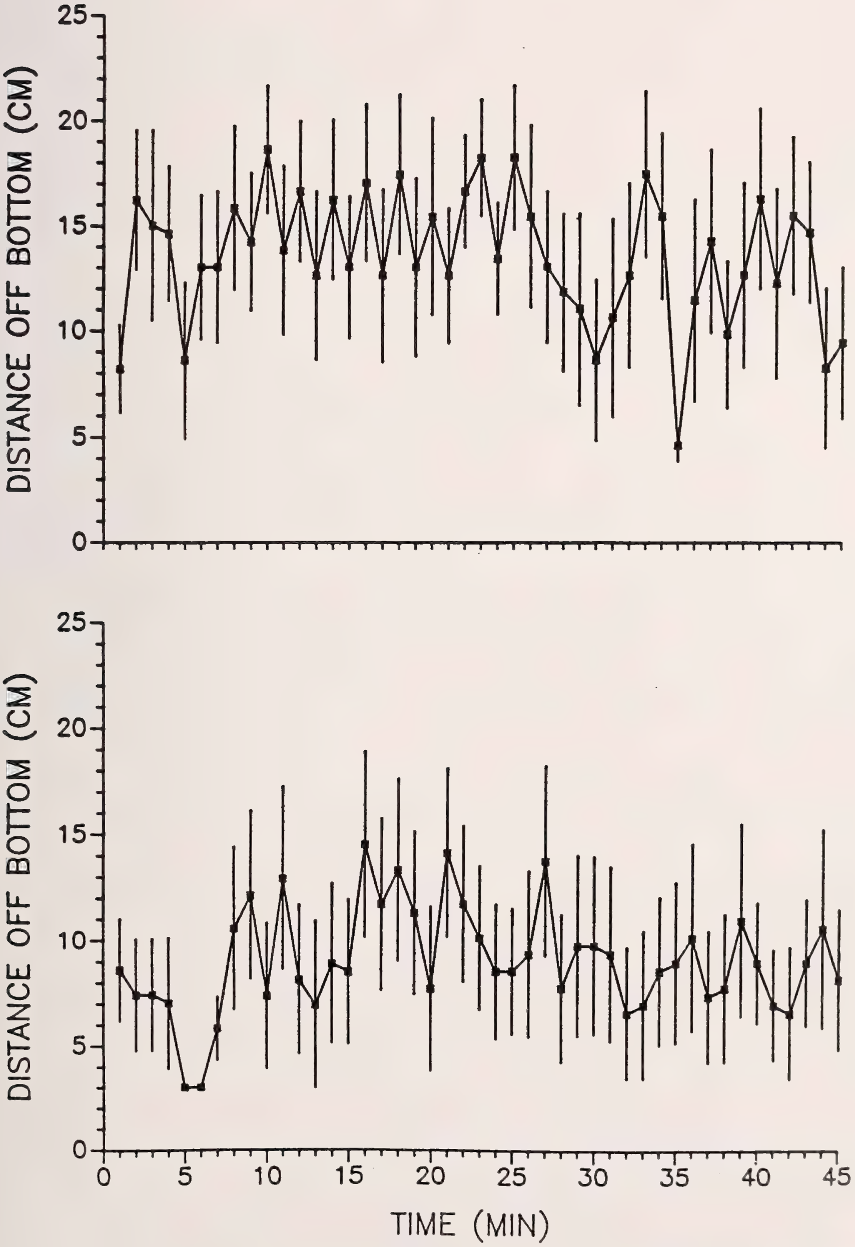

FIG. 1. Plot of mean vertical distance over time by treatment (normoxia, top; and hypoxia, bottom). Values are expressed as $\overline{X} \pm 1$ SE.

TABLE 2. Amount of time spent by each individual in each of three vertical levels within the experimental aquaria over a 45 minute time period. Paired values are given in percentages of total time (normoxic/hypoxic).

Vertical Position	Individual Number				
	1	2	3	4	5
Top (>16 cm)	24/45	82/36	4 /74	30/56	0 /18
Middle (8-15 cm)	14/33	10/20	4 / 4	26/20	7 / 9
Bottom (<8 cm)	62/22	8 /44	92/22	44/24	93/73

DISCUSSION—Among teleosts, a wide range of adaptations (hematological, respiratory, and behavioral) are known to compensate for changes in oxygen availability. Most fishes using periodically-hypoxic habitats like mangroves and tropical floodplains, however, generally do not possess adaptations for aerial respiration (Kramer et al., 1978) but are able to survive periods of hypoxia by other adaptations. For example, Winemiller (1989) documented the development of dermal lip proturbances in South American characid fishes only during hypoxic events. These proturbances are used for ASR and their appearance was found to be independent of fish size. Striped mullet *(Mugil cephalus)* not only use aerial respiration (Hoese, 1985) but move to the air-surface interface and use ASR when hypoxic conditions develop in mangrove habitats (per. observ.). Similarily, juvenile snook increased their distance off the bottom (Mean = 4.5 cm) and decrease their activity under hypoxia suggesting that they behaviorally adjust position in response to low oxygen. Snook behavior is identical to that described for other ASR species (Lewis, 1970; Kramer, 1987) and are also morphologically adapted to orient toward the atmosphere-water interface. Their protruding lower jaw potentially allows them to draw more highly oxygenated surface water into direct contact with the gills as has been documented in small, dorsally flattened fishes (Lewis, 1970; Kramer, 1987). Decreases in snook activity during hypoxia, as documented in this study, are associated with lower oxygen requirements in some teleosts (Doudoroff and Shumway, 1970). Davis (1975) indicated that a 50% reduction in available oxygen would limit energy expenditure for other daily needs. Additionally, surface breathing can clearly make a substantial contribution to arterial blood oxygenation in some teleosts (Burggren, 1982). Although this behavior may supply sufficient oxygen for small snook (about 50-60 g WW and 100-150 mm SL), larger snook greater than 60 g WW and 150 mm SL may not obtain sufficient oxygen from this behavior for it to be beneficial in hypoxic environments, even though they also move to the surface. This is supported by other data indicating that snook greater than 150 mm SL show significantly lower respiratory metabolism and greater mortality than snook less than 150 mm SL in identical low partial pressure conditions (Peterson and Gilmore, 1991).

Behavioral adjustments have been suggested to be the first of a suite of responses utilized by metazoans when dealing with environmental perturbations (Slobodkin and Rapoport, 1974). The movement toward more oxygenated surface waters in mangrove swamps would not only facilitate increased oxygen uptake but effectively remove fishes from the toxic H_2S rich bottom waters, which is hypothesized to contribute to fish kills (Abel et al., 1987). This behavior then seems adaptive to many fishes which frequent hypoxic water, particularily those with small body size such as small juvenile snook.

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LITERATURE CITED

ABEL, D. C., C. C. KOENIG, AND W. P. DAVIS. 1987. Emersion in the mangrove forest fish Rivulus marmoratus: a unique response to hydrogen sulfide. Env. Biol. Fishes 18:67-72.

BURGGREN, W. W. 1982. "Air-gulping" improves blood oxygen transport during aquatic hypoxia in the goldfish *Carassius auratus*. Physiol. Zool. 55:327-334.

CHEW, S. F., A. L. L. LIM, W. P. LOW, C. G. L. LEE, K. M. CHAN, AND Y. K. IP. 1990. Can the mudskipper, *Periophthalmus chrysospilos*, tolerate acute environmental hypoxic exposure? Fish Physiol. Biochem. 8:221-227.

DAVIS, J. C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. J. Fish. Res. Board Can. 32:2295-2332.

DOUDOROFF, P. AND D. L. SHUMWAY. 1970. Dissolved oxygen requirements of freshwater fishes. FAO Tech. Rept. # 86. 291 pp.

GILMORE, R. G. 1987. Fish, macrocrustacean and avian population dynamics and cohabitation in tidally influenced impounded subtropical wetlands. Pp. 373-394. *In:* WHITMAN, W. R. AND W. H. MEREDITH (eds.). Waterfowl and wetlands symposium. Delaware Dept. Nat. Res. Env. Control, Dover, Delaware.

HOCHACHKA, P. AND G. N. SOMERO. 1984. Biochemical Adaptation. Princeton Univ. Press, Princeton, N.J. 537 pp.

HOESE, H. D. 1985. Jumping mullet-the internal diving bell hypothesis. Env. Biol. Fish. 13:309-314.

KRAMER, D. J. 1987. Dissolved oxygen and fish behavior. Env. Biol. Fish. 18: 81-92.

KRAMER, D. L, C. C. LINDSEY, G. E. E. MOODIE, AND E.D. STEVENS. 1978. The fishes and the aquatic environment of the central Amazon basin, with particular reference to respiratory patterns. Can. J. Zool. 56:717-729.

LEWIS, W. M., JR. 1970. Morphological adaptations of cyprinodontoids for inhabiting oxygen deficient waters. Copeia 1970:319-326.

PETERSON, M. S. AND R. G. GILMORE. 1988. Hematocrit, osmolality and ion concentration in fishes: consideration of circadian patterns in the experimental design. J. Exp. Mar. Biol. Ecol. 121:73-78.

_________ AND R. G. GILMORE. 1991. Eco-physiology of juvenile snook, *Centropomus undecimalis* (Bloch): life-history implications. Bull. Mar. Sci. 48:46-57.

SAINT-PAUL, U. 1984. Physiological adaptation to hypoxia of a neotropical characoid fish *Colossoma macropomum*, Serrasalmidae. Env. Biol. Fish. 11:53-62.

SLOBODKIN, L. B. AND A. RAPOPORT. 1974. An optimal strategy of evolution. Quart. Rev. Biol. 49:181-200.

TABB, D. C., B. DRUMMOND, AND N. KENNY. 1974. Coastal marshes of southern Florida as habitat for fishes and effects of changes in water supply on these habitats. Final Rept., U.S. Dept. Interior, Bur. Sport Fish. Wildl., Branch of River Basins. (Contr. # 14-16-0004-56). 63 pp.

TAYLOR, D. S. 1988. Observations on the ecology of the killifish *Rivulus marmoratus* (Cyprinodontidae) in an infrequently flooded mangrove swamp. Northeast Gulf Sci. 10:63-68.

THAYER, G. W., D. R. COLBY, AND W. F. HETTLER. 1987. Utilization of the red mangrove prop root habitat by fishes in south Florida. Mar. Ecol. Prog. Ser. 35:25-38.

WINEMILLER, K. O. 1989. Development of dermal lip proturbances for aquatic surface respiration in South American characid fishes. Copeia 1989:382-390.

Florida Scient. 54(3/4): 173-178. 1991.
Accepted: Nov. 6, 1990.

Outstanding Student Paper Awards
Florida Academy of Sciences
Fifty-fifth Annual Meeting
St. Leo, May 1991

AGRICULTURAL SCIENCES

José R. Espaillat, Agronomy Department, University of Florida. "The Influence of Varied Stem Maturity on Rooting of *L. micromera* and *L. graveolens*." Graduate Co-award.

Peter A. Krottje, Agronomy Department, University of Florida, "Effect of Growth Regulators on *in vitro* Bud Formation and Shoot Elongation in Desmodium." Graduate Co-award.

ANTHROPOLOGICAL SCIENCES

Louis C. Forline, Department of Anthropology, University of Florida, "Dietary Taboos: The Convergence of Cognition, Gender, Cultural Ecology, and Health Perspectives in a Brazilian Fishing Village." Outstanding Student Award.

Kathleen Umland, Department of Anthropology, University of Florida, "Buur Heybe, Somalia: Understanding How the Geological Forces Influenced Cultural Development." Honorable Mention.

BIOLOGICAL SCIENCES

Mark Chiappone, Department of Biology, University of Miami, "A Comparison of Plotless Transects vs. Linear Percentage Sampling for Evaluating Stony Coral (Scleractinia and Milleporina) Diversity, Colony Density and Area Coverage on Reefs of the Exuma Cays Land and Sea Park, Bahamas." Undergraduate Award.

Leslie HaySmith, Department of Wildlife and Range Sciences, University of Florida, "Movement Patterns and Habitat Utilization of the Eastern Woodrat *(Neotoma floridana floridana)* in North Central Florida." Graduate Award.

COMPUTER SCIENCE AND MATHEMATICS

Lotfi Tadj, Department of Computer Science, Florida Institute of Technology, "The Lovasz Basis Reduction Algorithm and the Subset Sum Problem." Graduate Award.

ENGINEERING SCIENCES

Christine E. Kerschus, Department of Civil Engineering and Mechanics, University of South Florida, "Analysis of Culvert Performance Utilizing a Spreadsheet Program." Undergraduate Award.

Michael P. Moses, Department of Physics and Space Sciences, Florida Institute of Technology, "Development of a Hybrid Rocket Engine Prototype." Graduate Award.

ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCES

John T. Butcher, Millar Wilson Laboratory for Chemical Research, Jacksonville University, "Influence of Inorganics on the Determination of Elemental Carbon in Air Particulate Matter." Undergraduate Award.

N. Venkatraj, Institute of Environmental Studies, Department of Chemistry, University of South Florida, "Synthesis of a Novel Bis (B-Diketone) as a Precourser for an Organometallic Diastereoisomer." Graduate Award.

FLORIDA COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS

Vickie L. Larson, Department of Biological Sciences, Florida Institute of Technology, "Characterization of the Florida Landscape and Its Significance in the Conservation of Biodiversity." Graduate Award.

GEOLOGICAL AND HYDROLOGICAL SCIENCES

No Outstanding Student Paper awards presented.

MEDICAL SCIENCES

Maria Ibanez, Department of Biological Sciences, Florida Institute of Technology, "Comparative Studies on Decontaminants Against *M. gordonea*." Undergraduate Award.

Susan Hunter, Department of Molecular Biology and Microbiology, University of Central Florida, "Cross-reactivity of the Pollens of *Paspalum notatum* (Bahia), *Callistemon citrinis* (Bottlebrush) and *Melaleuca leucadendron* (Melaleuca). Graduate Award.

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ON THE ECOLOGY OF YOUNG SEA TURTLES

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Abstract: *This paper is a study of sea turtle hatchling, post-hatchling, and sub-adult behavior and growth. Some of my here-to-fore unpublished observations on jellyfish in Florida coastal waters, scatophagy by captive green turtles and long-term survival of headstarted green turtles are reported. The effects of ocean currents on such turtles are considered as well as information on the oceanic distribution of suitable food resources.*

Over the years, much research has been done on nesting sea turtles, their eggs and the hatchlings while they are in the nest and going from the nest to the sea. There has also been much speculation about the unanswered questions regarding what the hatchlings do after they enter the sea. I suggest alternative behavioral patterns that may be available to hatchlings/post-hatchlings at sea. By looking at their behavior from the point of view of what they may do, rather than what they must do, we may be better able to understand their limitations and capabilities.

Materials and Methods—The technique of headstarting, tagging and release of sea turtles has been described by Schmidt and Witham (1961), Witham and Futch (1977), Witham (1976, 1980), and Fontaine, et al., 1985, 1988). Observations of swimming activity and orientation were made of hatchlings and headstarted sea turtles entering the sea. Feeding activities of captive hatchling and subadult green turtles were made.

Results—Tag return data from 151 (0.84%) of more than 18,000 headstarted green sea turtles, *Chelonia mydas* provide information regarding their oceanic dispersal, survival and growth. One hundred twenty three (81%) of these turtles were alive when captured, 20 (13%) were dead when found and the status of 8 (5%), either living or dead, was unknown. The discrepancy between 99% and 100% resulted from rounding of the percentages. Tag return data were provided by individuals and organizations too numerous to list. While the majority of tag returns came from coastal areas of the eastern United States, the distribution of other tag returns ranged from the eastern Atlantic to the Caribbean, the western Gulf of Mexico and South America. Ehrhardt and Witham (1990) suggested an age at first maturity of 19-24 years for Florida headstarted green turtles. This estimate does not vary greatly from the Frazer and Ehrhart (1985) estimate of 18-27 yrs. for age at maturity for Florida green turtles.

Discussion *Nest Emergence*—Emergence from the nest, described by Hendrickson (1958) and Carr and Ogren (1960), involves group activity apparently resulting from stimulation of the group when "restless" individuals near the bottom of the group become active. Final emergence from the nest appears to be temperature dependent (Hendrickson, 1958; Mrsovosky, 1968) and it is likely that all emergence activity is temperature dependent within, as yet undetermined, minimum and maximum range.

Sea Finding—The factors (or behavior) involved in finding the sea after leaving the nest were described by Carr and Ogren (1960) and Mrsovosky and Shettleworth (1968). It is evident that light is a major factor in orienting the hatchlings to the sea. However, the means by which the hatchlings establish and maintain their offshore swim has been less well understood.

Offshore Swim—About 50 years ago, Deraniyagala (1939) commenting on factors that could influence sea turtle distribution observed that the winds associated with two monsoons, one from the north-east and the other from the south-west resulted in either clockwise or counter clockwise currents around the island of Ceylon (now Sri Lanka). Much later, Carr and Ogren (1960) reported on the increased activity of green turtle hatchlings as they encountered the wave wash on the beach, and Carr (1967) described his concept of an inborn offshore swim orientation cue. He suggested that the turtles responded to the effects of waves washing over them. My observations during the releases of more than 18,000 headstarted green turtles, *Chelonia mydas*, (Witham, 1988) and significant numbers of hatchling loggerheads, *Caretta caretta*, are that, if they are impacted by waves of sufficient force as to "get their attention," that they orient seaward and continue to swim in that direction. The headstarted turtles were disoriented when I released them at times when there were no waves, or when closely spaced waves with short time intervals were coming from different directions. Prang (1976) provided additional evidence in support of a wave force mechanism for orienting the offshore movement of young sea turtles. He observed that yearling green turtles would not swim when currents were 0.5 km or less. Stoneburner and Richardson (1982) reported that hatchling loggerheads *(Caretta caretta)* swam against longshore currents. More recently others (Salmon and Wyneken, 1987; Salmon and Lohmann, 1989; and Wyneken, et al., 1990), while studying the effects of wave forces by using a wave tank and oceanic observations, determined that both waves and swells were sufficient to determine the swimming direction of hatchling turtles. It is possible that "imprinting" magnetically (Lohmann, 1989) for a future geographic nesting area occurs during the offshore swim. Orientation into waves and currents is not unique to young sea turtles. For example, Walton and Herrnkind (1977) reported that spiny lobsters, *Panulirus argus* responded to currents and waves and suggested that such a response could be "...useful to animals moving to and from beaches for reproduction (e.g. sea turtles *(Chelonia)*, ..."

Unfortunately, the unproven assumption that hatchling turtles had an innate directional drive (Carr, 1967) gained acceptance (Frick, 1976) and is used as the justification of research studies and policy recommendations of releasing hatchlings and headstarted turtles offshore instead of allowing them to swim seaward from a release beach (Caillouet, et al., 1987; Manzella, et al., 1988). This project "imprints" Mexican Kemp's ridley *(Lepidochelys kempi)* sea turtles by hatching the eggs in Padre Island, Texas beach sand, allows the hatchlings to crawl down the Padre Island beach and then collects them for headstarting as they reach the surf. The headstarted turtles are released at selected offshore or near shore sites, and lose any opportunity to imprint during their offshore swim.

Oceanic Dispersal—It is well documented that some nesting females show some degree of nesting site fidelity, cyclically returning to the same beach to nest during intervals of many years (Carr, et al., 1978). Without doubt, the most widely known hypothesis about sea turtle dispersal is based upon Carr's (1967) idea that they are "imprinted" to their natal beach. This hypothesis holds that when the turtles reach maturity they return to their natal beach to nest. Implicit in this hypothesis is the need to assume some sort of directing mechanism such as genetic separation of nesting "populations" for their specific nesting area (Carr and Coleman, 1974; Carr, et al., 1978; Mortimer and Carr, 1987). I suggest that population should be used to describe all members of a particular species, and that colony (Meylan, et al., 1990) be used to describe particular nesting beach aggregations.

By contrast, Hendrickson (1958) proposed that social facilitation could account for turtles establishing nesting site fidelity. He suggested that the maturing turtles join and follow already mature turtles going to a nesting beach that they are familiar with. Under this hypothesis, the turtles of any particular ocean basin system could be genetically homogeneous.

Either the natal beach imprint hypothesis or the social facilitation hypothesis could explain the loss of nesting colonies from beaches they once used. Extirpation of the nesting females for a particular colony could, according to the natal beach imprint hypothesis, result in no hatchlings to be imprinted for that particular beach. On the other hand, extermination of the females familiar with a particular beach could, under the social facilitation hypothesis, end the recruitment of new nesting females there.

Tag return data for the Florida Department of Natural Resource's (FDNR) headstart program (Witham, 1976, 1980; Witham and Futch, 1977) suggests that young green and loggerhead turtles do not follow a stage based migratory pattern.

For green turtles, Meylan and co-workers (1990) established mitochondrial (mtDNA) differences for Aves Island, Ascension Island and the Turtuguero, Costa Rica/ Florida complex. These authors claim that these colonies of green turtles "...must be managed on a colony-specific basis" is questionable. To support natal beach homing it seems likely that there should be mtDNA differences in the Florida/Costa Rica complex such as those found in Chesapeake Bay striped bass, *Morone saxatilis* (Chapman, 1990). Additionally, the Meylan and co-workers (op. cit.) speculation that their Florida samples might have derived from Costa Rican green turtles headstarted and released in Florida is further cause to question the natal beach hypothesis. I headstarted and released those turtles, which were sent to me as hatchlings by the late Prof. Archie Carr. Since all of the Costa Rican green turtles successfully headstarted in Florida were hatched in Costa Rica, the speculation argues for the need to continue green turtle headstarting research. Their assumption also raises a question about the biological need for the species to return to a natal beach for nesting. If "imprinting" for a nesting geographic area occurs during the offshore swim it is possible that any nesting colony's hatchlings, or headstarted yearlings, could adapt to any other geological nesting area where they were released.

The apparent propensity of some green turtles to return to their natal beach for nesting is made more confusing by evidence that a green turtle tagged during a non-nesting emergence on Aves Island was later observed nesting on Mona Island, Puerto Rico (Kontos, et al., 1988). Furthermore, Genero Solé (1990) believed that this turtle could have nested without having been seen on Aves Island on a night other than when it was tagged.

Genetic isolation would suggest that any reproductively isolated colony within a particular ocean basin is more in danger of extinction than colonies retaining interbreeding capability (Simpson and Beck, 1965).

In addition, observations of hatchling and post-hatchling sea turtles of different species in captivity and at sea reveal varying swimming patterns and speeds (Salmon and Wyneken, 1987; Wyneken, 1988) which could affect their ultimate oceanic dispersal by causing them to reach different parts of major ocean currents. Most often young green turtles swim by using the front flippers for propulsion; their rear flippers are sometimes used as rudders for changing direction. On the other hand, loggerheads will frequently swim by using their rear flippers only in a dog-paddle fashion. Charles Caillouet (1988) advised me that Kemp's ridleys, *Lepidochelys kempi* also use the rear flipper swim mode. Witham's (1977) observations of leatherbacks, *Dermochelys coriacea,* in captivity agree with those of Davenport (1987) that the young of this species swim almost incessantly by using strong front flipper strokes.

I presented a model for the effect of ocean current on sea turtle hatchlings swimming offshore from Cape Florida, Dade County, Florida (Witham, 1980). They would be advected by the nearshore Florida Current, a major current that becomes the Gulfstream as it flows northward from Florida. Farther north in Florida and along the southeastern coast of the United States the western edge of the current system is well offshore. Collard (1987, 1990) discussed the effects of ocean currents on the dispersal of Kemp's ridley *(Lepidochelys kempi)* hatchlings.

The oceanic dispersal of young sea turtles depends upon the current system that they enter. Local currents may be southerly, northerly, easterly or westerly and they may be strong, weak, or almost nonexistent where hatchlings begin their offshore swim. As they continue their hatchling/posthatchling swimming during foraging, resting, or possibly responding to local wind driven waves, their ocean-current mediated dispersal model will be continually changing (Frick 1976; Prang, 1976; Witham, 1980; Salmon and Wyneken, 1987).

Discrete Oceanic Habitat Hypothesis—Carr and Ogren (1960) considered young green turtles to be primarily carnivorous with a shift to a mainly herbivorous diet as adults. This shifting feeding pattern suggested to these authors that the species would need to have varying habitats during its developmental stages. This hypothesis led Carr (1967) to believe that small turtles used the food resources to be found associated with sargassum weed. However, associating with sargassum may not provide a safe haven for hatchling sea turtles (Witham, 1988). There is evidence of mortalities resulting from apparent entanglement, the attraction of pelagic predators of hatchling sea turtles to weedlines, and the apparent lack of drifting sargassum offshore of some sea turtle nesting beaches. Caldwell (1968) reported on dead small loggerheads washed ashore along Florida's east coast that were assumed to have been in association with the sargassum prior to being stranded, because sessile growths on the turtles were the same as those found on drifting sargassum. Carr (1987) reported 18 cases of hatchling/posthatchling strandings and two cases of such turtles taken from the stomachs of predators. Most of the stranded turtles were associated with sargassum wrack. My first experience with a hatchling sea turtle occurred when I retrieved a small amount of sargassum, approximately 30 cm^3, from a weak surf (Witham, 1988). There was a moribund hatchling loggerhead in the sargassum and my efforts to revive the turtle were fruitless. I reported on eight loggerhead hatchlings and one green hatchling found in the stomach of a dolphinfish, *Coryphaena hippurus,* that was caught while the fisherman was trolling alongside a sargassum weedline (Witham, 1974). It is common knowledge among Florida sport fishermen that fishing the weedlines often provides better catches than open ocean trolling. Helfman (1981) suggested that the shade provided by drifting material could assist fishes in capturing their prey. Drifting sargassum weed and other floating objects, either living or nonliving, could provide the shade needed to assist these predators of young sea turtles. Carr and Meylan (1980) reported seeing three green turtle hatchlings in sargassum weed east of Costa Rica and noted that while they were observing them two of the hatchlings were eaten by frigatebirds, *Frigata sp.*

Later, Carr (1986) appeared to dismantle his sargassum association hypothesis and erect one attributing a "vital" role in young sea turtle survival to the biomasses concentrated by ocean current convergences. It was his opinion "...that there would be no sea turtles of the kinds we know if there were no fronts." However, Carr (1987) seemingly reassigned a significant role to sargassum in the pelagic survival of young sea turtles.

Oceanic Food Resources—Deraniyagala (1939) mentioned scyphomedusae from the stomach of a leatherback turtle and Brongersma (1970) suggested that salps were important in the diet of leatherbacks. Witham (1977) and Witham and Futch (1977) presented evidence that hatchling/post-hatchling leatherbacks, greens, and loggerheads grew well in captivity when fed one species of jellyfish, *Cassiopea xamachana.* I suggested (Witham, 1976) that young green turtles would find sufficient food resources at sea to assure their survival, and it has not been suggested that hatchling/posthatchling leatherbacks need to associate with either sargassum or convergence caused biomasses to survive.

There is evidence of widespread distribution of cniderians in the oceans away from fronts or convergences. Mayer (1910) at times observed masses of medusae on the sea surface during calm weather. Additional evidence of the widespread distribution and abundance of gelatinous zooplankton (Biggs, et al., 1981) has been provided by other researchers (Harbison, et al, 1978; Brownlee, 1987; Arai, 1987; Aldredge and Silver, 1988). In early June of 1948 I flew at an altitude of about 915 m (1,000′) along Florida's east coast from near Titusville to the St. Lucie Inlet. During this flight of about 150 kms (>90 miles), jellyfish were visible on the sea surface from near shore to the limits of offshore visibility. This enormous "patch" of jellyfish did not have the narrow band characteristics of the confluence described by Beebe (1926), and it was unassociated with any evidence of a rip current or convergence. Later, Leary (1957) observed a large number of leatherback turtles with carapace lengths estimated to be from 3.5 to 6 feet (approximately 1.3 to 2 m) apparently feeding on a large concentration of jellyfish, *Stomolophus meleagris*, in the surf northward from Port Aransas, Texas.

Lane and co-workers (1965) compared the extracellular amino acids of the jellyfish, *Aurelia aurita* and the Portuguese-man-of-war, *Physalia physalia* and, while they did not analyze the cellular proteins, it seems likely that the extracullar amino acids would be an easily available source of nutrition for sea turtles.

Historically, the post "lost year" Atlantic green turtle may not have had the nutrition limitation described by Bjorndal (1985). True (1887) described the extensive fishery for green turtles in Florida lagoonal and coastal waters and Parsons (1962) reviewed the history of this species' decline from what must have been an enormous population. Under these circumstances the numbers of turtles inhabiting coastal sea grass beds might have kept significant areas of the beds closely cropped—thus providing themselves with the more nutritious new growth. Selective feeding on turtle grass, *Zosteria marina,* parts near the roots was noted by Audubon (*In* True, 1884). This selective feeding did not appear to be related to maintaining grazing areas (Bjorndal, 1985), since "large fields" of floating, uneaten plant parts were found in the feeding areas. Bjorndal (op.cit.) reported that even when feeding on new growth the species' hind-gut fermentation process was insufficient to provide adequate nutrition for them to achieve their genetic growth potential.

There could be another step, now largely missing due to reduced populations, in the species' feeding strategy. True (1884) reported that some Florida turtle-fishermen caught green turtles that were feeding on floating balls of grass that turtles had rolled and cemented together with clay. Since these turtles do not appear to have the ability to roll and cement grass with their mouths, it is most likely that they were feeding on fecal material that had been nutritionally enriched during the digestive process of green turtles feeding on seagrasses (Thayer, et al., (1982). My previously unpublished observations of immature green turtles in captivity support this hypothesis. Those turtles were skatophagous when being fed the fibrous stems of sea purslane, *Sesuvium portulacasturm*. The plant stems were excreted as rolled-up masses that could have been described as being cemented together.

Oceanic Predation—Predation is generally recognized as the way of life for many marine animals. Small sea turtles are mainly carnivorous predators that are, in turn, subjected to predation by sea birds, fishes and sharks (Hirth, 1971; Witham, 1974; Carr and Meylan, 1980; Stancyk, 1981). Beebe (1926) reported evidence of overwhelming numbers of bird, fish, and shark predators of young sea turtles associated with a current convergence. Hunter and Mitchel (1967) as well as Shomura and Matsumoto (1982) reported on the presence of predacious fishes associated with flotsam and fish attracting devices. While Mortimer (1988) suggested that oceanic predation of hatchlings is greatly reduced after they reach water depths of about 10 m (approximately 30 ft.), the observations of the above authors as well as Heyerdahl (1971) and Callahan (1986) attest to the abundance of predators on the high seas.

Carr (1986) cited Beebe (1926), Hunter and Mitchell (1967) and Shomura and Matsumoto (1982) in support of his hypotheses regarding a "vital" association of young sea turtles with ocean current biomass accumulations. However, their reports provide evidence only of the presence of larger turtles. Carr (1986) significantly altered Beebe's (1926) quotation of the Arcturus log to read, ". . . turtles drifted past. . ." instead of the original, "Two large turtles drifted peacefully past. . . ." Hunter and Mitchell (1967) reported seeing only one green turtle of an unstated size associated with flotsam. Since these authors included a section commenting on sea snakes, *Pelamis platuras*, associated with the flotsam, evidence of the presence of sea turtles during their studies appears to be limited to a single specimen. Shomura and Matsumoto (1982) did not report the presence of any sea turtles around fish attracting devices (FADS). Harbison and co-workers (1986) believed that, because of reduced predation, marine animals that are capable of surviving on the average quantities of food distributed in the open ocean would be at a selective advantage over prey animals associated with ocean current caused biomass accumulations. Witham (1988) suggested that young sea turtles would be safer from predation and that they would be able to find sufficient quantities of gelatinous zooplankton for their survival and growth if they were behaving as individuals in the pelagic environment away from drifting sargassum and other current concentrated marine biomasses.

There has been considerable speculation regarding sea turtle hatchling pigmentation (e.g., Caldwell, 1968) and its role in reducing predation. The major benefit of the sargassum-like pigmentation to loggerhead hatchlings could be that non-swimming hatchlings appear to predators to be undesirable bits of sargassum.

Oceanic Growth—Growth rates for wild green turtles appear to vary greatly. Schmidt (1916) reported growth rates for wild, sub-adult green turtles and Frazer and Ladner (1986) developed a growth curve based upon Schmidt's data. Estimated growth rates for wild Florida green turtles were made by Frazer and Ehrhart (1985). Balazs (1982) suggested that green turtles require from about 10 years to more than 58 years to mature in different parts of the Hawaiian Archipelago, while Zug and Balazs (1985) felt that greens from warmer waters would grow faster and mature earlier. Limpus (1979) estimated that some Australian green turtles might take 50 years to mature. Witham (1980) suggested that Western Atlantic green turtles would mature in 15 to 20 years. Such great variations in growth rates suggest that efforts to establish age/size classes (Frazer and Ehrhart, 1985) would be very difficult, if not impossible, for this species. Zug (1990) suggested that Kemp's ridley *(Lepidochelys kempii)* do not reach maturity until they are approximately 11-12 years old.

Tag and recapture data (Schmidt, 1916; Witham and Futch, 1977; Ehrhart et al., 1987; Bjorndal and Bolton, 1988) suggest that sub-adult green turtles are highly migratory. These data indicate that the green sea turtle in particular could have a second poorly understood stage. This stage, which extends from the largest lagoonal sizes observed by Ehrhart (1990) to maturity, might represent a return to a more pelagic existence. Since only large size turtles were reported by Beebe (1926) in association with a confluence biomass and Leary (1957) saw only larger leatherbacks associated with a concentration of jellyfish, it is possible that the second missing link in the life history of green turtles could benefit from association with such systems at sea. The extremely long maturation times suggested by some data could represent growth data for turtles that would never become mature if they remained in the ecological niche where such slow growth rates were observed.

Oceanic Survival—While there is concern for the survivability of released headstarted sea turtles (Mortimer, 1988), tag return data suggest that the Florida headstarted greens adapt well to their oceanic habitat. To date, the longest-term survival of Florida headstarted green turtles has been for turtles in their tenth and thirteenth years of freedom. Turtle No. A3825 was caught in Cuba in its 13th year of freedom, No. A5076 was also caught in Cuba after approximately 10.5 years of freedom and No. A9675, was caught in Mexican waters after slightly more than 10 yrs. and 1 mo. of freedom. Additionally, there have been 23 tags returned for turtles free less than 1 year, 14 free about 1 year, 14 about 2 years, 8 about 3 years, 6 for over 4 years, 5 for over 5 years, 3 for over 8 years, and 1 for over 9 years. All of these returns were for individual turtles and there never was a mass stranding such as reported by Caldwell (1968) for loggerheads.

Tag returns for the Florida headstarted green turtles have been received from along the Atlantic seaboard of the United States as far north as New York, the Eastern Atlantic (Azores, Maderia, and Mauritania), South America (Colombia, Venezuela, Guyana, and Brazil), the Bahama Islands, the Greater and Lesser Antilles Islands, and the Gulf of Mexico.

Conclusions—After hatchling or headstarted sea turtles enter the sea, the offshore swim may provide the "imprinting" for them to return to their natal or release geographic area.

Mitachondrial DNA studies suggest only that sea turtles nest in sometimes widespread geographical areas, rather than specific natal beaches.

The three current hypotheses regarding sea turtle hatchling survival and dispersal (sargassum association, current caused biomass association, and individual survival at sea away from sargassum or biomass accumulations) are not mutually exclusive. There is evidence of significant predation and stranding mortalities associated with sargassum. No creditable evidence has been presented to support the presence of hatchling survival in current accumulated biomasses. The individual survival at sea away from sargassum and biomasses could result in less predation, but this hypothesis needs testing, if possible, and evaluation.

Sea turtle headstarting, particularly the Florida green turtle program, has provided valuable data on oceanic dispersal, survival and growth, and suggests the need to continue such studies.

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LITERATURE CITED

Alldredge, A. L. and M. W. Silver. 1988. Characteristics, dynamics and significance of marine snow. Prog. Oceanogr., 20:41-82.

Arai, M. N. 1987. Interactions of fish and pelagic colenterates. Can. J. Zool. 66:1913-1927.

Balazs, G. H. 1982. Growth rates of immature green turtles in the Hawaiian Archipelago. Pp 117-126 *In* Bjorndal, K. A. (ed.) Biology and Conservation of Sea Turtles, Smithsonian Institution Press, Washington, D. C.

Beebe, W., 1926. Where Currents Rip: The Arcturus Adventure. Putman's Sons, New York and London: 41-70.

Biggs, D. C., R. R. Bidigare and D. E. Smith. 1981. Population Density of gelatinous macrozooplankton: *In situ* estimation in oceanic waters. Biol. Oceanogr. 1(2):157-173.

Bjorndal, K. A. 1985. Nutritional ecology of sea turtles. Copeia 1985(30):736-751.

———— and A. B. Bolton. 1988. Growth rates of immature green turtles, *Chelonia mydas*, on feeding grounds in the southern Bahamas. Copeia 1988 (3):555-564.

Brongersma, L. D., 1970. Miscellaneous notes on turtles. III. Proc. K. Ned. Akad. Wet. Ser. C., Biol. Med. Sci., 73:324-335.

Brownlee, S. 1987. Jellyfish aren't out to get us. Discover, August, 1987:42-54.

Caldwell, D. K. 1968. Baby loggerhead turtles associated with *Sargassum* weed. Quart. Jour. Fla. Acad. Sci., 31(4):271-272.

Caillouet, C. W., Jr. 1988. Swimming behavior of small Kemp's ridley sea turtles. NMFS-SWFC Galveston Laboratory, Galveston, Texas. Pers. Commun.

————, C. T. Fontaine, T. D. Williams, S. A. Manzella, K. L. W. Indelicato, M. C. Duronslet, D. B. Revera, A. M. Landry, Jr. and P. J. Howes. 1987. The Kemp's ridley sea turtle research project: An Annual Report for Ficsal Year 1986. NOAA Tech. Memo. NMFS-SEFC-192.

Callahan, S. 1986. Adrift: Seventy-six Days Lost at Sea. Houghton Mifflin Company, Boston: 234 pp.

Carr. A. 1967. So Excellent a Fishe. The Natural History Press, Garden City, New Jersey.

________. 1986. Rips, FADS, and little loggerheads. BioScience 36(2):92-100.

________. 1987. New perspectives on the pelagic stages of sea turtle development. Conserv. Biolog., 1(2):103-121.

________, M. Carr, and A. Meylan. 1978. The ecology and migrations of sea turtles, 7. The western Caribbean green turtle colony. Bull. Amer. Mus. Nat. Hist., 162(1):1-46.

________, and P. Coleman. 1974. Seafloor spreading theory and the odyssey of the Green turtle. Nature 249 (5453) 128-130.

________, and A. B. Meylan. 1980. Evidence of passive migration of *Chelonia mydas* hatchlings in Sargassum Copeia (2):366-368.

________, and L. Ogren. 1960. The ecology and migrations of sea turtles, IV. The green turtle in the Caribbean Sea. Bull. Amer. Mus. Nat. Hist. 121:1-48.

Chapman, R. W. 1990. Mitochordrial DNA analysis of striped bass populations in Chesapeake Bay. Copeia 2:355-366.

Collard, S. B. 1987. Review of oceanographic features relating to neonate sea turtle distribution and dispersal in the pelagic environment: Kemp's ridley *(Lepidochelys kempi)* in the Gulf of Mexico. Final Report Contract No. 40-GFNF-5-00193, NOAA/NMFS, Panama City, Florida: 1-42, 14 figs.

________ 1990. The influence of oceanographic features on post-hatchling sea turtle distribution and dispersion in the pelagic environment. Abstract. Tenth Ann. Workshop Sea Turtle Biology and Conservation, Hilton Head Island, South Carolina, February 20-24, 1990.

Davenport, J. 1987. Locomotion in hatchling leatherback turtles, *Dermochelys coriacea*. J. Zool., London 212:85-101.

Deraniyagala, P. 1939. The tetrapod reptiles of Ceylon, vol 1. Testudinates and Crocodilians. The Director, Colombo Museum, Ceylon (now Sri Lanka) or Dulau & Co., Ltd., 29 Dover Street, London, W. I., England.

Ehrhardt, N. M. and R. Witham. 1990. Analysis of growth of the green sea turtle *(Chelonia mydas)* in the Western Central Atlantic. In press. Bull. Mar. Sci.

Ehrhart. L. M., W. E. Redfoot and W. C. Booker. 1987. Studies of the ecology of Indian River Lagoon marine turtle populations and marine turtle nesting beach productivity in South Brevard County, Florida. Report to Florida Department of Natural Resources Bureau of Marine Research: 1-29 + 35 Tables.

________. 1990. History, population structure and ecology of marine turtles of the Indian River Lagoon System. In press. *In:* Draft Marine Resources Council Esturine Monograph Series Robert F. Krieger Pub. Co., Inc. Melbourne, Fla.

Fontaine, C. T., K. T. Marvin, T. D. Williams, W. J. Browning, R. M. Harris, K. L. W. Indelicato, G. A. Shattuck, and R. A. Sadler. 1985. The husbandry of hatchling to yearling Kemp's ridley sea turtles *(Lepidohelys kempi)*. NOAA Tech. Memo. NMFS-SEFC-158, 34 pp.

________, T. D. Williams and D. B. Revera. 1988. Care and maintenance standards for Kemp's ridley sea turtles *(Lepidochelys kempi)* held in captivity. NOAA Tech. Memo. SEFC-NMFS-202: 15 pp.

Frazer, N. B. and L. M. Ehrhart. 1985. Preliminary growth models for green, *Chelonia mydas*, and loggerhead, *Caretta caretta*, turtles in the wild. Copeia 1:73-79.

________ and R. C. Ladner. 1986. A growth curve for green sea turtles, *Chelonia mydas*, in the U. S. Virgin Islands, 1913-14. Copeia 3:798-802.

Frick, J. 1976. Orientation and behavior of hatchling *Chelonia mydas* in the sea. Anim. Behav. 24(4):849-857.

Harbison, G. R., L. P. Madin, and N. R. Swanberg. 1978. On the natural history and distribution of oceanic ctenophores. Deep-Sea Res., 25:233-256.

________, V. L. McAlister, and R. W. Gilmer. 1986. The response of the salp, *Pegea confoederata*, to high levels of particulate material: Starvation in the midst of plenty. Limmnol. Oceanogr., 31(2):371-382.

Helfman, G. 1981. The advantage to fishes of hovering in shade. Copeia 1981(2):392-400.

Hendrickson, J. R. 1958. The green sea turtle, *Chelonia mydas* (Linn.) in Malaya and Sarawak. Proc. Zool. Soc. Lond. 130:455-535.

Heyerdahl, T. 1971. The RA Expeditions. Doubleday & Company, Garden City, New York: 341 pp.

Hirth, H. 1971. Synopsis of the Biological Data on the Green Turtle, *Chelonia mydas* (L.) 1758. FAO Fisheries Synopsis No. 85:76 pp.

HUNTER, J. R. AND C. T. MITCHELL. 1967. Association of fishes with flotsam in the offshore waters of Central America. Fish. Bull. 66:13-29.

KONTOS, A., S. ECKERT, AND K. ECKERT. 1988. Inter-island migration of nesting green turtle, *Chelonia mydas*. Marine Turtle Newsletter, No. 42:101.

LANE, C. E., E. PRINGLE, AND A. M. BERGERE. 1965. Amino acids in the extracellular fluids of *Physalia physalis* and *Aurelia aurita*. Comp. Biochem. Physiol., 15:259-262.

LEARY, T. R. 1957. A schooling of leatherback turtles, *Dermochelys coriacea*, on the Texas coast. Copeia 3:172-253.

LIMPUS, C. 1979. Notes on growth rates of wild turtles. Mar. Turt. Newsletter, 10:3-5.

LOHMANN, K. J. 1989. Magnetic orientation by hatchling loggerhead sea turtles. P. 101, *In:* ECKERT, S. A., K. A. ECKERT, AND T. H. RICHARDSON (compilers). Proc. Ninth Annual Workshop Sea Turtle Consev. Biology. NOAA Tech. Memo. NMFS-SEFC-232.

MANZELLA, S. A., C. W. CAILLOUET, JR., C. T. FONTAINE, T. D. WILLIAMS, K. L. W. INDELICATO, M. C. DURONSLET, D. B. REVERA, A. M. LANDRY, JR., AND E. M. STABENAU. 1988. Kemp's ridley head start and sea turtle research at the Galveston Laboratory: Annual Report-Fiscal Year 1987. NOAA Tech. Memo. NMFS-SEFC-201.

MAYER, A. G. 1910. Medusae of the World, 3 vols. Carnegie Institute of Washington, Washington, D. C.

MEYLAN, A. B., B. W. BOWEN, AND J. C. AVISE. 1990. A genetic test of the natal homing versus social facilitation models for green turtle migrations. Science 248:724-727.

MORTIMER, J. A. 1988. Management priorities for sea turtles: re-evaluating priorities. Florida Defenders of the Environment, Bull. 25, May-June 1988: unpaginated.

_________ AND A. CARR. 1987. Reproduction and migration of the Ascension Island green turtle *(Chelonia mydas)*. Copeia 1:103-113.

MRSOVOSKY, N. M. 1968. Nocturnal emergence of hatchling sea turtles: control by thermal inhibition of activity. Nature, Lond., 220 (5174):1338-1339.

_________ AND S. SHETTLEWORTH. 1968. Wavelength preferences and brightness cues in the water finding behaviour of sea turtles. Behaviour XXXII:211-257.

PARSONS, J. J. 1962. The Green Turtle and Man. Univ. Florida Press, Gainesville, Florida.

PRANG, H. D. 1976. Energetics of swimming of a sea turtle. J. Exp. Biol. 64:1-22.

SALMON, M. AND K. J. LOHMANN. 1990. Orientation by hatchling loggerhead sea turtles *Caretta caretta* L. in a wave tank. J. Exp. Mar. Bio. Ecol. Vol. 139:41-50.

_________ AND J. WYNEKEN. 1987. Orientation and swimming behavior of hatchling loggerhead turtles *Caretta caretta* during their offshore migration. J. Exp. Mar. Biol. Ecol. 109:137-153.

SCHMIDT, J. 1916. Marking experiments with turtles in the Danish West Indies. Meddelerser. fra Kommissionen for Havundersogesler, Serie Fiskeri 5:1-26.

SCHMIDT, S. AND P. R. WITHAM. 1961. In defense of the turtle. Sea Frontiers 7(4):215-217.

SHOMURA, R. AND W. MATSUMOTO. 1982. Structural flotsam as fish aggregating devices. NOAA Tech. Memo. SWFC 22:1-8.

SIMPSON, G. G. AND W. S. BECK. 1965. Life: An Introduction to Biology, (ed. 2). Harcourt, Brace & World, Inc. New York

SOLE, G. 1990. Letter regarding green turtle nesting on Aves Island, Venezuela. FUNDENA, Apdto Postal 70376, Caracas 1071A, Venezuela. Pers. commun.

STANCYK, S. E. 1981. Non-Human Predators of Sea Turtles and Their Control. Pp. 139-152. *In:* BJORNDAL, K. A. (ed.) Biology and Conservation of Sea Turtles. Proc. World Conf. Sea Turtle Conserv., Washington, D. C. 26-30 November 1979:

STONEBURNER, D. L. AND J. I. RICHARDSON. 1982. Observations on the Movement of Hatchling Sea Turtles. Copeia, 4:963-965.

THAYER, G. W., D. W. ENGLE, AND K. A. BJORNDAL. 1982. Evidence for short-circuiting of the detritus cycle of seagrass beds by the green turtle, *Chelonia mydas* L. J. Exp. Mar. Biol. Ecol., 62:173-183.

TRUE, F. W. 1884. The useful aquatic reptiles and batrachians of the United States. Pp 137-162. *In:* GOODE, G. B. (ed.) The Fisheries and Fisheries industries of the United States. U. S. Comm. Fish and Fisheries, Sec. I, Part II.

_________. 1887. The turtle and terrapin fisheries. Pp 493-503. *In:* GOODE, G. B. (ed.) The Fisheries and Fisheries Industries of the United States. U. S. Comm. Fish and Fisheries, Sec. V, Vol. II, Part XIX.

WALTON, A. S., AND W. S. HERRNKIND. 1977. Hydrodynamic orientation of spiny lobster, *Panulirus argus* (Crustacea: Palinuridae): Wave surge and unidirectional currents. Proc. Ann.

Northwestern Mtg. Anim. Behav. Soc. 1977 Plenary Papers. Univ. of New Foundland. Mar. Sci. Res. Lab., Tech Rept. No. 20:184-211.

WITHAM, R. 1974. Neonate sea turtles from the stomach of a pelagic fish. Copeia 1974(2):548.

________. 1976. Evidence for ocean-current mediated dispersal in young green turtles, *Chelonia mydas* (Linnaeus). Masters Thesis, Univ. Oklahoma, Norman Oklahoma.

________. 1977. *Dermochelys coriacea* in captivity. Mar. Turtle Newsletter IUCN/SSC, 3:6.

________. 1980. The "lost year" question in young sea turtles. Amer. Zool., 20:525-530.

________. 1988. Abstract. Drifting sargassum weed: Safe haven or increased risk for hatchling sea turtles? P. 129 *In:* SCHROEDER, B. A. (compiler). Eighth Ann. Workshop Sea Turtle Conserv. and Biol. Fisher, NOAA Tech. Memo. NMFS-SEFC-214.

________ AND C. R. FUTCH. 1977. Early growth and oceanic survival of pen-reared sea turtles. Herpetologica 33(4):404-409.

WYNEKEN, J. 1988. Comparative and functional considerations of locomotion in turtles. Ph.D. dissert. Univ. Illinois-Urbana-Champaign. Urbana, Illinois.

________, M. Salmon, and K. L. Johnson. 1990. Orientation by hatchling loggerhead sea turtles *Caretta caretta* L. in a wave tank. J. Exp. Mar. Biol. Ecol. 139:41-50.

ZUG, G. R. 1990. Estimates of age and growth in *Lepidochelys kempii* from skeletochronological data. In Press. Tenth Ann. Sea Turtle Workshop Sea Turtle Biol. Conserv., Hilton Head Island, S. C. Feb. 20-24, 1990.

________ AND G. H. BALASZ. 1985. Skeletochronological age estimates for Hawaiian green turtles. Marine Turtle Newsletter, 33:9-10.

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ZOOPLANKTON OF IMPOUNDED MARSHES AND SHALLOW AREAS OF A SUBTROPICAL LAGOON[1]

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ABSTRACT: *The zooplankton of two impounded salt marshes and that of shallow areas of the Indian River Lagoon, in east-central Florida are compared. A total of 63 distinct taxa were collected during the two-year study. The copepods* Oithona nana *and* Acartia tonsa *accounted for almost 90% of the total number of individuals captured. Mean plankton density at the study sites was 403,291 individuals per cubic meter, which is somewhat higher than densities reported in similar studies elsewhere. There were significant differences in numbers of taxa and densities between sites and years. Average number of taxa was highest at the less isolated sites, whereas densities were highest at a site with intermediate isolation, and lowest at the most isolated site. Peaks in zooplankton densities occurred in late summer and early fall and followed the first heavy rains of the season. Isolating an impounded marsh from the lagoon during the summer by closing the culverts connecting the two areas did not appear to have a significant impact upon the zooplankton communities of either site, but maintaining an impounded marsh isolated during the whole year may have resulted in reduced zooplankton density and diversity.*

THE view of marine and estuarine net zooplankton as the most important link in their food webs has recently been challenged. It is now recognized that the 'microbial loop' may play a dominant role in cycling materials and energy, and that a great deal of primary production may pass through a pool of dead organic matter before it becomes available to organisms in higher levels of these food webs (Fenchel, 1988). Nevertheless, marine and estuarine plankton are still important energetic links in these systems. Zooplankton populations can have a significant influence on higher food web levels (Day et al., 1989), can be important in the remineralization and transport of nutrients (Harris, 1959), may serve as indicators of physical conditions within the estuary (Jeffries, 1962), and often reflect the overall health of marshes and estuaries (Odum et al., 1963).

Over 16,000 ha of salt marshes and mangrove forests along the Indian River Lagoon, in east central Florida, have been impounded for mosquito control (Rey and Kain, 1990). Impoundments are created by building dikes around the marshes so that water can be maintained on their surface during the salt marsh mosquito breeding season, which in this area runs approximately from May to October. This technique effectively eliminates mosquito production from the impounded areas since the salt marsh mosquitoes *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Walker) will not oviposit upon standing water. Management of the impoundments usually entails closing the culverts connecting the impounded marsh with the lagoon in late spring and flooding the marsh with water pumped from the lagoon. In the fall, the culverts are opened to restore the marsh-lagoon connection.

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Perimeter ditches, which parallel the dikes on the inside of the impoundments are created as material is excavated for dike construction. These ditches are, in many ways, analogous to tidal creeks, and are a critical habitat for aquatic organisms inhabiting these marshes (Gilmore, 1987). Although a great deal of work has been done on fishes, macrocrustaceans, and physical conditions of these impounded marshes (Schooley, 1980; Harrington and Harrington, 1982; Gilmore et al., 1982; Gilmore, 1987; Rey et al., 1986; 1990), no information is available on their zooplankton communities. Below we compare the plankton communities of two impounded salt marshes along the Indian River Lagoon, and that of shallow areas of the lagoon. The impounded marshes differ in physical conditions and in their relative isolation from the lagoon as a result of differences in their management.

Study Sites—The study sites are located on a barrier island forming the east side of the Indian River Lagoon, in east-central Florida (30.48°N, 80.75°W). Impoundments IRC #12 (50.4 ha) and SLC #24 (122 ha) were once part of a single marsh that was impounded in 1965 (Fig. 1). In 1970, an internal dike was constructed separating the marsh into two individual impoundments. At the time of this study, the northern impoundment (IRC #12) was connected to the lagoon through a single 46 cm diameter culvert at its south end, whereas the southern cell (SLC #24) had no connection to the lagoon. In 1982, the culvert at IRC #12 remained open during the entire year. It was closed on July 12, 1983 in an attempt to flood the marsh for mosquito control without having to pump lagoon waters and re-opened on September 27, 1983. On September 30, 1983, a second 46-cm culvert was installed at the northern end.

At IRC #12, sampling stations were established in the perimeter ditch near the south culvert (Culvert), and in a small shallow pond, 0.3-1.2 m in depth at the northwest end of the perimeter ditch (Mole Hole). The latter site becomes isolated from the rest of the impoundment when water levels are low. At SLC #24, a station was established in the perimeter ditch (SLC). A station was also established in a shallow (0.5-1.5 m) flat in the lagoon, immediately west of the impoundments (Lagoon). Isolation of the stations increases as one progresses from the Lagoon to the Culvert station (directly connected to the lagoon during most of the year), to Mole Hole (connected to the lagoon through the parimeter ditch from which it becomes frequently isolated) and finally to SLC (no lagoon connection).

Methods—Samples were collected bi-weekly using pump and net samplers designed to operate in shallow areas with muddy bottoms. Each sampling episode included one sample each with 63μ pump samplers and with 63μ compressed-mouth nets. Our sampling techniques are described in detail in Rey and co-workers (1987).

Sample Processing—After each sample, the contents of the collecting screens (pumps) and vessels (nets) were washed into glass jars and were stained and preserved with a solution of 10% buffered formaldehyde and 100 mg/l rose bengal. In the laboratory, each sample was washed through a 63μ sieve, and large organisms such as adult fish and insects were removed, washed

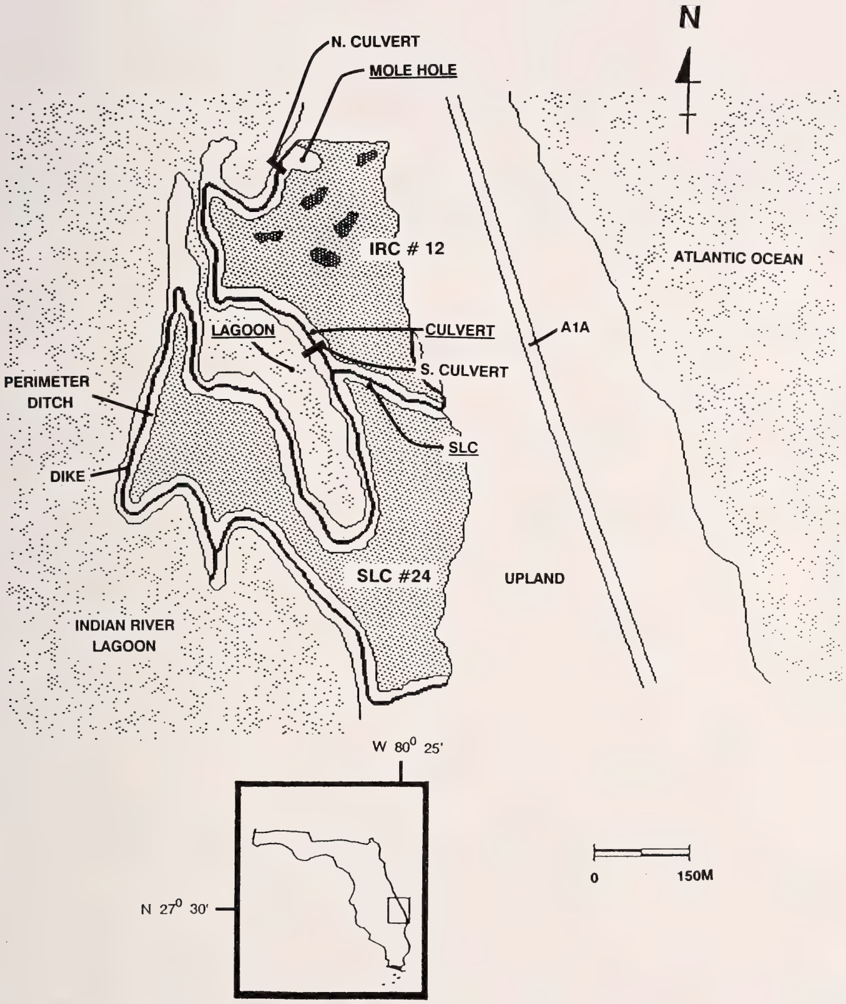

FIG. 1. Map of the study area and sampling stations.

over the sieve, and stored in 70% ethanol. The rest of the sample was diluted to a known volume and five subsamples were removed with a Hensel-Stempel pipette. The organisms in each subsample were identified to the lowest taxonomic level possible and counted in a Bogorov tray.

Physical Data—The following physical variables were recorded at each site during each sampling event: salinity (A/O temperature compensating refractometer), dissolved oxygen and water temperature (YSI model 51B meter), and pH (Corning model 610A meter). Water levels were recorded at all stations, and precipitation was continuously monitored at IRC #12.

Data Analysis—All data management and analyses were performed with the RS/1 system (BBN Software—Cambridge, MA), and with SAS (SAS Institute—Cary, NC). The data from the pump and net samples were pooled. Data for adult fish and adult macroinvertebrates were not included in the analyses. Density data were log (x + 1) transformed to stabilize the variance, whereas analyses on numbers of taxa were performed on the untransformed data.

Differences between stations in physical conditions, and in plankton abundance and diversity were examined using a nested (station, year-within-station) ANOVA. To investigate differences between years, one-way ANOVAs were performed on a reduced data set that included only the data from May 19, 1982 to December 21, 1982 (Year 1) and from May 11, 1983 to December 20, 1983 (Year 2); this allowed us to perform individual comparisons for each station between analogous time periods of the two years. The Waller-Duncan *a-posteriori* test (WDT) was used to explore significant differences in means of physical variables, density, and numbers of taxa between sites and years.

To investigate seasonal patterns in species composition, cluster analyses were run on the untransformed density data, as described by Fulton (1984). We used the UPGMA clustering method with beta = −0.25 and (1–Morisita's (1959) similarity index) to generate between-sample distance matrices based upon the presence and abundance of the different taxa.

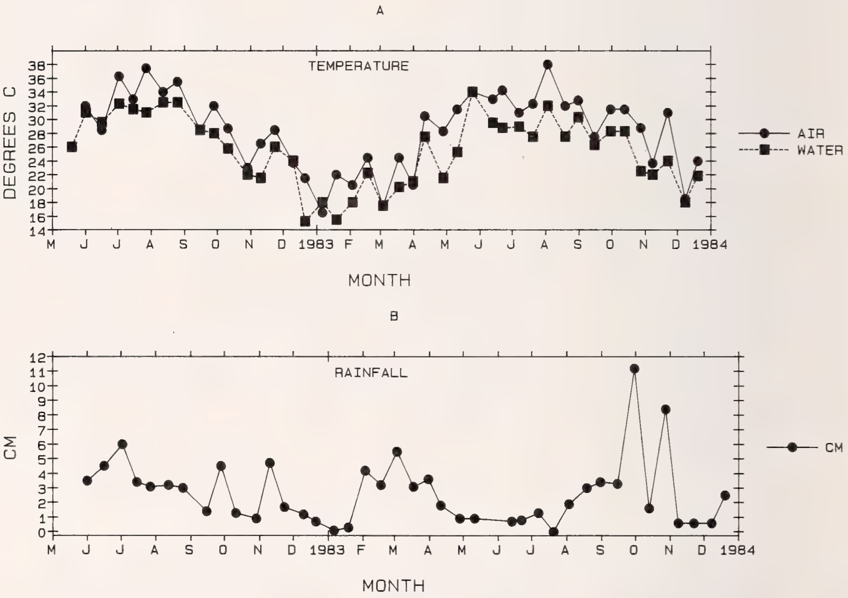

FIG. 2. Temperature and rainfall during the study.

RESULTS—*Physical Data*—Air temperature, water temperature, and salinity during this study followed the typical patterns for this region, with highest values during summer, and lowest during winter. High precipitation occurred during September-November of 1982 and 1983, during June and July of 1982, and during February-April of 1983. The drier months were December and January of both years, and May to August of 1983 (Fig. 2). In general, physical conditions were more variable (higher coefficient of variation) at Mole Hole and SLC, than at the Lagoon and Culvert stations (Table 1). At all sites, D.O. was higher in winter and lowest during the summer; the highest (13.8 ppm) and lowest (0.2 ppm) dissolved oxygen levels were recorded at Mole Hole, followed by SLC (0.40, 10.50 ppm) and then by the Culvert (1.40, 7.80 ppm) and Lagoon (1.40, 7.80 ppm) stations (Table 1). pH extremes ranged from 7.13 at Mole Hole to 8.8 at SLC, but the differences between sites through time were always small.

TABLE 1. Descriptive statistics for the physical data recorded at the sampling stations. Air and water temperatures are reported in degrees C, salinity in ppt, D.O. in ppm, and mean water level in cm.

Variable	N	Mean	S.E.	C.V.	Min.	Max.
MOLE HOLE						
Air Temp.	41	28.52	0.87	19.57	16.50	38.00
Water Temp.	42	25.57	0.78	19.87	15.25	34.00
D.O.	42	3.78	0.51	87.31	0.20	13.80
Salinity	42	30.62	1.38	29.25	16.00	52.00
pH	40	7.89	0.06	4.56	7.13	8.55
Water Level	37	0.36	0.07	116.36	−0.73	1.22
CULVERT						
Air Temp.	40	28.05	0.85	19.23	16.20	38.50
Water Temp.	42	25.03	0.89	23.15	13.00	37.25
D.O.	42	3.43	0.22	40.58	1.40	7.80
Salinity	42	27.05	0.95	22.77	17.00	47.00
pH	40	7.89	0.05	3.98	7.20	8.60
Water Level	35	1.47	0.13	51.77	0.79	5.14
LAGOON						
Air Temp.	40	28.34	0.86	19.28	16.25	38.50
Water Temp.	42	24.35	0.83	21.96	12.25	32.50
D.O.	42	3.21	0.21	42.47	1.30	7.20
Salinity	42	26.35	0.74	18.15	15.00	35.00
pH	40	7.93	0.04	3.46	7.30	8.75
Water Level	34	3.28	0.06	10.63	2.82	4.15
SLC						
Air Temp.	40	27.61	0.77	17.59	15.50	35.50
Water Temp.	41	24.69	0.78	20.33	13.25	35.30
D.O.	41	3.89	0.44	21.90	0.40	10.50
Salinity	41	17.63	0.99	36.26	7.00	35.00
pH	40	7.93	0.06	4.59	7.18	8.80
Water Level	38	0.57	0.10	110.09	−0.48	3.06

There were significant differences among stations in salinity (ANOVA, $F_{3,163} = 27.63$, $p \leq 0.0001$) and mean water level ($F_{3,140} = 194.30$, $p \leq 0.0001$). Salinity was highest at Mole Hole (MH) and lowest at SLC (SL), with the Culvert (CU) and Lagoon (LA) stations intermediate between the two (WDT: MH $>$ CU $=$ LA $>$ SL; $p \leq 0.05$). Water levels were highest at the Lagoon, followed by the Culvert station, and then by SLC and Mole Hole (WDT: LA $>$ CU $>$ SL $=$ MH; $p \leq 0.05$). There were no significant differences between years for any of the physical variables measured.

Faunal Composition and Density—A total of 63 distinct taxa were identified from our collections. Of these, 34 were collected at Mole Hole, 43 at the Culvert station, 48 at the Lagoon, and 37 at SLC. Mean plankton density per sample was 403,291 individuals/m^3, with adult and immature copepods dominating the collections (Table 2). The calanoid copepod *Acartia tonsa* (mean density = 28,021 individuals/m^3), and the cyclopoid *Oithona nana* (69,996 individuals/m^3) accounted for close to 90% of the total number of individuals collected (excluding immature copepods). Other copepods such as *Tortanus setacaudatus, Metis holothuriae, Ergasilus* sp., *Euterpina acutifrons,* and *Scottolana canadensis* were captured frequently and were sometimes abun-

TABLE 2. Mean density (number/cubic meter), percent of total, and frequency of occurrence of the most abundant taxa collected at all stations.

Taxon	Density	%	Frequency
Oithona nana	69,996	52.9	0.95
Acartia tonsa	28,021	27.0	0.72
Polychaete larvae	3,998	5.1	0.52
Gastropod veligers	3,846	4.9	0.46
Balanus sp. nauplii	1,383	1.5	0.44
Euterpina acutifrons	1,370	1.3	0.39
Metis holothuriae	1,191	1.2	0.50
Ergasilus sp.	1,165	1.2	0.25
Scottolana canadensis	1,067	1.0	0.68
Tortanus setacaudatus	781	0.9	0.23
All plankton	403,291	—	—
All copepods	104,166	—	—
Copepod nauplii	245,889	—	—

dant, as was the branchyuran *Argulus* sp., but individually they accounted for less than 5% of the total catches. Polychaete larvae, gastropod veligers, brachyuran zoea, and barnacle nauplii were also common (Table 2).

Meroplanktonic species were more abundant in the less isolated stations (Lagoon and Culvert) than in the more isolated ones (Mole Hole and SLC). The ctenophore *Mnemiopsis mccradyi* was sporadically abundant during spring and summer but we have no quantitative density data for this species since specimens almost always disintegrate during transport (Miller, 1974).

Some typically benthic taxa such as nematodes, foraminiferans, and harpacticoid copepods such as *Metis holothuriae* were often captured in our samples. Ostracods and some parasitic taxa such as the branchiuran *Argulus* sp. and the copepod *Ergasilus* sp. were also common at times. Adult fish (7 species), insects and arachnids (8 taxa), and adult macroinvertebrates (2 species) were collected infrequently.

There were few consistent correlations between physical variables and plankton diversity and abundance. Overall plankton density was positively correlated with water temperature (Spearman Rank Correlation, $r=0.237$, $p \leq 0.01$, $N=132$), pH ($r=0.186$, $p \leq 0.05$, $n=126$) and rainfall ($r=0.217$, $p \leq 0.01$, $n=120$), whereas numbers of taxa were positively correlated with mean water level ($r=0.501$, $p \leq 0.001$, $N=116$). A. *tonsa* densities were negatively correlated with water temperature ($r=-0.296$, $p \leq 0.001$, $N=132$) and salinity ($r=-0.205$, $p \leq 0.01$, $N=132$), and positively correlated with mean water level ($r=0.632$, $p \leq 0.001$, $N=116$). *O. nana* density was positively correlated with water temperature ($r=0.170$, $p \leq 0.05$, $N=132$), rainfall ($r=0.170$, $p \leq 0.01$, $N=120$) and salinity ($r=0.233$, $p \leq 0.01$, $n=132$) and negatively correlated with D.O. ($r=0.258$, $p \leq 0.01$, $n=132$).

Temporal Patterns—Seasonal patterns in density were similar at the Lagoon, Mole Hole and Culvert stations. At these stations, zooplankton densities exhibited late spring-summer minima followed by late summer-early fall peaks with secondary lows in the winter (Fig. 3A). During 1982, there were

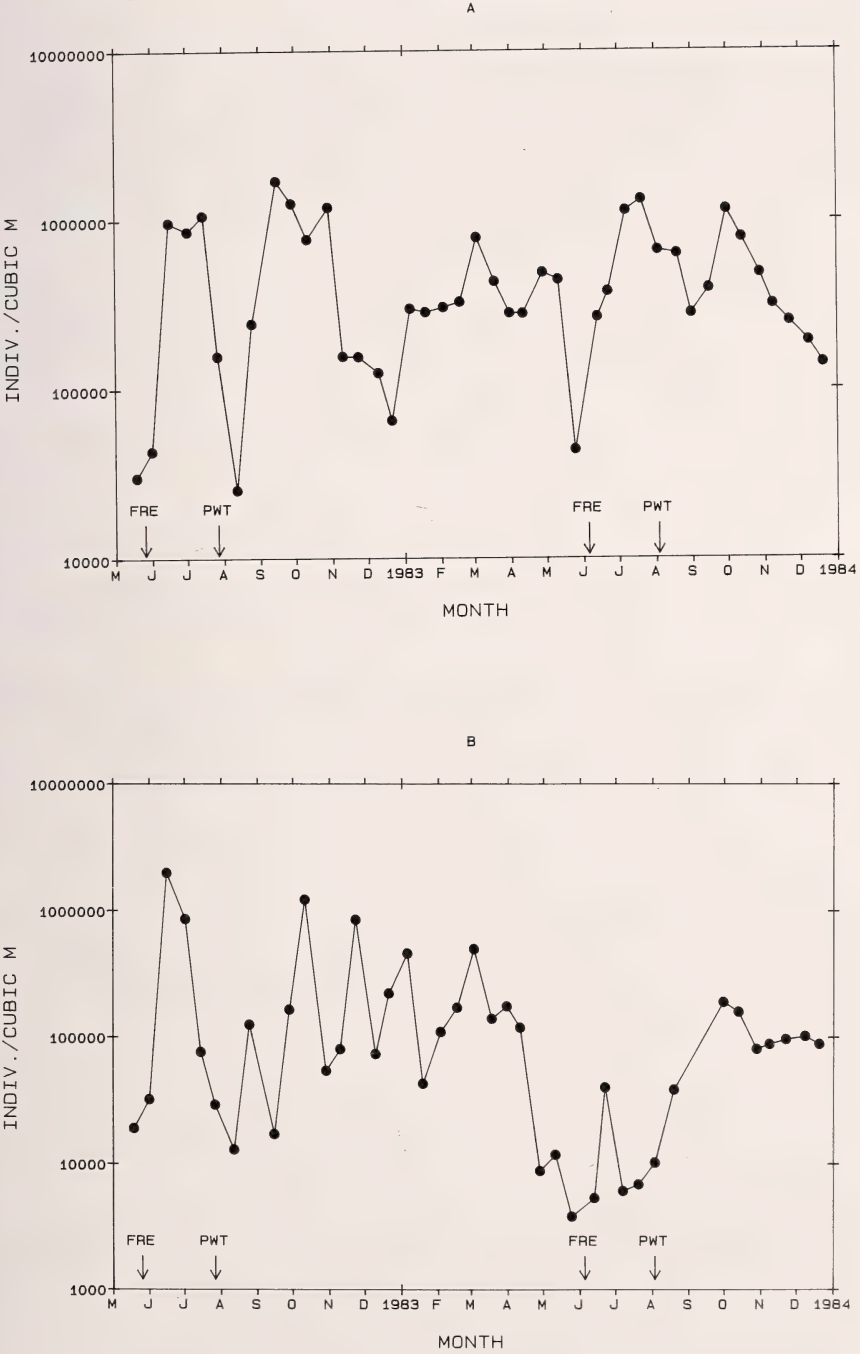

FIG. 3. (A) Mean plankton densities from the Mole Hole, Culvert and Lagoon stations; (B) Plankton density at SLC. FRE = first heavy (>35 mm) rainfall event of the season, PWT = highest water temperature of the season.

two summer lows one in late May and the second in mid-August, followed by a September bloom, whereas during 1983 there was only a single (late May) minimum followed by a late July peak (Fig. 3A). The winter (Dec.-Jan.) minima at these stations were comparable during both years. At SLC, the summer drops in density follow the above pattern, but no winter declines were evident during either year (Fig. 3B). *A. tonsa* was most abundant during winter and spring, in all stations whereas the highest densities of *O. nana* occurred during the summer and fall.

There were no consistent seasonal patterns in the numbers of taxa captured, but at all stations except Mole Hole, there was a trend of decreasing number of taxa from 1982 through 1983 (Fig. 4). A majority of the common taxa, including most of the meroplanktonic ones, were present throughout the year at least in some of the stations. Notable exceptions include brachyuran zoea, ostracods, and foraminiferans, which were absent during the winter.

Cluster analysis did not reveal any consistent grouping of samples according to season. In all cases there was considerable spread of samples from the same season into different clusters, even if the data for *A. tonsa* and *O. nana* were excluded from the analysis and the stations were considered individually.

Site-Year Comparisons—There were significant differences in numbers of taxa and zooplankton densities collected at the various stations (Table 3). More taxa were collected in Lagoon and Culvert samples than in SLC samples, which in turn returned higher numbers of taxa than Mole Hole; collec-

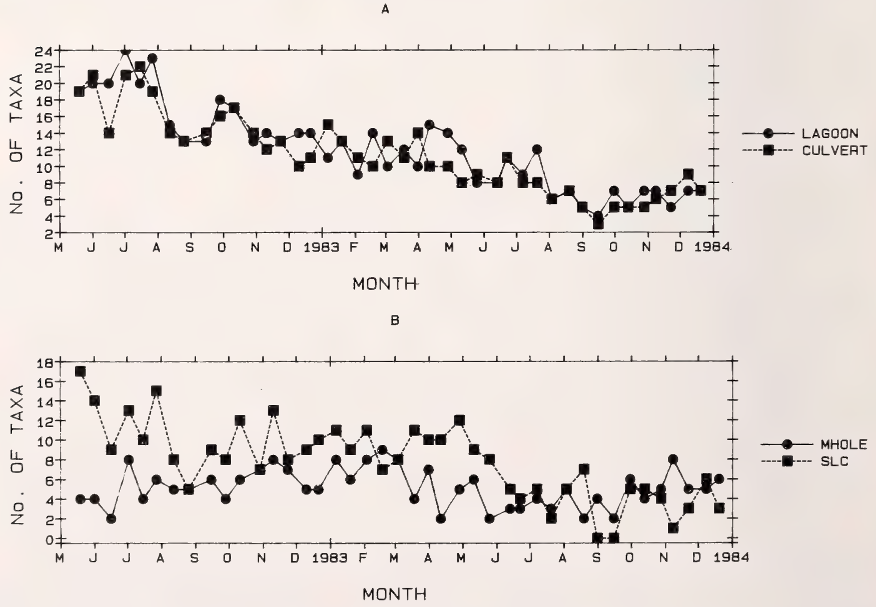

FIG. 4. Number of taxa collected at the study sites. (A) Lagoon and Culvert, (B) Mole Hole and SLC.

TABLE 3. Results of analyses of variance for differences in numbers of taxa and density between stations and years. (A) shows the result of a nested ANOVA for all stations, (B) the comparison of years within individual stations. LA = Lagoon, CU = Culvert, SL = SLC, MH = Mole Hole. In (A), entries under 'MEANS' indicate the rankings produced by the Waller-Duncan test; in (B) the relative magnitude of the year means.

Source	F[1]	p≤	Means
		(A)	
DENSITY			
Station	4.50	0.0050	MH > CU = SL
Yr (Station)	5.29	0.0001	—
NUMBER OF TAXA			
Station	78.88	0.0001	LA = CU > SL > MH
Yr (Station)	34.65	0.0001	—
		(B)	
DENSITY			
Mole Hole	17.12	0.0002	Y1 > Y2
Culvert	1.08	0.3113	—
Lagoon	1.40	0.2496	—
SLC	4.98	0.0429	Y1 > Y2
NUMBER OF TAXA			
Mole Hole	3.50	0.0708	—
Culvert	70.89	0.0001	Y1 > Y2
Lagoon	74.83	0.0001	Y1 > Y2
SLC	37.37	0.0001	Y1 > Y2

[1] A) STATION = $F_{3,156}$; YR (STATION) = $F_{8,156}$. B) = $F_{1,31}$

tions from Mole Hole, however, returned higher densities than those from SLC and the Culvert stations. Significantly more taxa were collected during year 1 than during year 2. Densities during year 2 were higher than during year 1 only at Mole Hole and SLC (Table 3).

DISCUSSION—The composition and densities of the zooplankton collected at our sites is fairly typical of shallow estuaries and marshes in North America. Collections are dominated by a few adult and immature copepods, with other copepods and meroplanktonic organisms becoming abundant at times.

We consider the benthic taxa commonly collected in our samples (nematodes, foraminiferans, and harpacticoid copepods) to be part of the local plankton since at our sites they are routinely found in the water column as a result of wind and tide-promoted mixing in these very shallow waters (see also Schooley, 1980). Although ostracods, which were also common in some of our samples, are primarily benthic, certain species, particularly in the Myodocopida and Podocopida, are known to have planktonic inclinations (Gosner, 1971). Likewise, the parasitic *Argulus* sp. and *Ergasilus* sp. are known to readily detach from their hosts and are commonly found swimming freely (Davis and Williams, 1950; Gosner, 1971).

Overall, total plankton, and total copepod mean densities were higher than those collected in similar studies in North America (Cronin et al., 1962; Hopkins, 1977; Knatz, 1978; Evans & Granger, 1980; Fulton, 1984). Mean densities of *A. tonsa*, *O. nana* and *E. acutifrons* were higher than those found at other Florida locations (Reeve, 1975; Hopkins, 1977; Table 2), while those of *O. colcarva* (298 individuals/m^3) were much lower. Polychaete larvae, and barnacle nauplii densities (Table 2) were similar to those reported from Florida but lower than those collected by Fulton (1984) in North Carolina.

The higher overall plankton densities collected in our sites than in other North American estuaries may be a result of high phytoplankton densities and nutrient concentrations in this part of the Indian River. Mahoney and Gibson (1983) demonstrated that lagoon nutrient levels and phytoplankton densities near Vero Beach are generally much higher than those normally found in other North American estuaries. Part of the reason for this is that accumulations of nutrients from surrounding farms, citrus groves, cattle ranches, etc. are often channeled directly to the lagoon through an extensive network of canals and floodgates.

The seasonal patterns of zooplankton abundance, with summer crashes and fall peaks, is relatively common among sub-tropical, and warm-temperate plankton communities, and are often correlated with phytoplankton blooms (Bacon, 1971). Studies of phytoplankton dynamics in the Indian River lagoon indicate that blooms tend to occur following the first heavy rainfall event of the summer (Youngbluth et al., 1976; Mahoney and Gibson, 1983). These authors attribute this phenomenon to an increase in nutrients, which are washed into the lagoon as runoff, or through the flood control canals. Our data are consistent with that hypothesis; peaks in zooplankton density also occur shortly after the first heavy rainfall event of the season and secondary peaks, such as those evident in March and October of 1983, also correlate with periods of high precipitation (Figs. 2 and 3). The lack of a winter crash at SLC may be a result of the closed nature of that system, where nutrients are re-cycled *in situ*, and phytoplankton blooms are common, even in winter (J.R., pers. obs.).

As in South Florida (Reeve, 1975), the summer declines in plankton abundance at our sites are likely the result of a combination of factors including high summer temperatures, low dissolved oxygen, low water levels, and increased salinities, all of which have been shown to adversely affect zooplankton populations (Cuzon du Rest, 1963; Reeve, 1975; Ambler, 1985). The lack of sharp summer drops in density by *O. nana* was probably due to the fact that this species is more tolerant of high salinities and high temperatures than *A. tonsa*, and also because it may be better able to handle the smaller phytoplankton fraction (Lampitt, 1978) which predominates in the lagoon during summer (Mahoney and Gibson, 1983). *O. nana* has been reported as being most abundant in the higher salinity areas of Tampa Bay (Hopkins, 1977) and Louisiana (Cuzon du Rest, 1963). Likewise, in our study this species was more abundant at the highest salinity station (Mole Hole) and least abundant at the lowest salinity one (SLC).

Predation may have also been important in reducing summer plankton densities. For example, *Mnemiopsis* spp. which sometimes became abundant at our sites during the summer, have been shown to significantly influence plankton abundance in various marsh and estuarine habitats (Nelson, 1925;

Barlow, 1955; Heinle, 1974; Fulton, 1984) and may have been particularly effective at our stations, where water exchange during the summer was very low or nonexistent. Juveniles of many fish species that are year-round residents of these impoundments, particularly *Cyprinodon variegatus*, *Gambusia affinis*, and *Poecilia latipinna* are important zooplankton consumers, as are seasonal impoundment residents such as juvenile mullet *(Mugil* spp.), ladyfish *(Elops saurus)*, and snook *(Centropomus undecimalis* — G. Gilmore, unpublished data). Mullet, whose juveniles enter these marshes during the summer (G. Gilmore, pers. comm.), are particularly abundant in the study area (Gilmore, 1987).

Differences between stations in numbers of taxa and zooplankton densities are related to their degree of isolation. The fact that more taxa were collected at the more open stations than at the more isolated ones (Table 3) may result from one or more of the following factors: (1) Some taxa may not be able to maintain populations at the isolated sites without continuous recruitment from outside, (2) Isolation reduces the number of rare and transient species collected, and (3) Physical conditions at Mole Hole and SLC (greater salinity extremes, more variable D.O. and water levels) may prevent some species from inhabiting these stations during part or all of the year.

The fairly consistent differences between years in number of taxa and density (Table 3) are not easily understood in terms of the particular management schemes at the different sites and can not be attributed to closure of the culverts at IRC #12, as similar patterns were observed in the Lagoon and in SLC. Our data do not allow us to make any inferences about differences in zooplankton production between years or sites as abundance and production are not always closely related (Day et al., 1989).

Conclusion—The plankton communities at the study sites are a diverse assemblage, but with strong numerical dominance by *Acartia tonsa* and *Oithona nana*, and with overall densities that are somewhat higher than those reported from similar studies elsewhere. Rainfall, salinity, temperature, and isolation appear to be important in regulating zooplankton abundance and diversity in time and space. The subtropical climate of the area is probably responsible for the lack of definite differences in species composition during the different seasons.

We could not identify any clear effect of impounding *per se* upon the plankton communities at the study sites, but impoundments that are totally isolated from the lagoon appear to have less diverse and abundant zooplankton communities than impoundments with tidal connections. We found no significant differences in the composition and dynamics of the zooplankton of impoundment perimeter ditches and that of shallow areas of the lagoon. However, increased zooplankton densities were found in areas of the ditch that became periodically isolated from the rest of the impoundment.

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LITERATURE CITED

Ambler, J. W. 1985. Seasonal factors affecting egg production and viability of eggs of *Acartia tonsa* Dana from East Lagoon, Galveston, Texas. Est. Coast. Shelf Sci. 20:743-760.

Bacon, P. R 1971. Plankton studies in a Caribbean estuarine environment. Caribb. J. Sci. 11:81-90.

Barlow, J. P. 1955. Physical and biological processes determining the distribution of zooplankton in a tidal estuary. Biol. Bull. 109:211-225.

Cronin, L. E., J. C. Daiber, and E. M. Hulbert. 1962. Quantitative seasonal aspects of zooplankton in the Delaware River estuary. Chesapeake Sci. 3:63-93.

Cuzon du Rest, R. 1963. Distribution of the zooplankton in the salt marshes of southern Louisiana. Publ. Inst. Mar. Sci. Univ. Texas 9:132-155.

Davis, C. D. and R. H. Williams. 1950. Brackish water plankton of mangrove areas in southern Florida. Ecology 31:519-531.

Day, J. W., C. A. S. Hall, W. M. Kemp, and A. Yáñez-Arancibia. 1989. Estuarine Ecology. John Wiley & Sons, New York, N.Y.

Evans, M. S. and E. H. Granger. 1980. Zooplankton in a Canadian arctic estuary. Pp. 199-210. *In:* Kennedy, V. S. (ed.), Estuarine Perspectives. Academic Press, New York, N.Y.

Fenchel, T. 1988. Marine plankton food chains. Ann. Rev. Ecol. Syst. 19:19-38.

Fulton, R. S., III. 1984. Distribution and community structure of estuarine copepods. Estuaries 7:38-50.

Gilmore, R. G. 1987. Fish, macrocrustacean, and avian population dynamics and cohabitation in tidally influenced impounded subtropical wetlands. Pp. 372-394. *In:* Whitman, W. R. and W. H. Meredith (eds.), Waterfowl and Wetlands Symposium. Delaware Dept. of Natural Resources, Dover.

_________, D. W. Cooke, and C. J. Donohoe. 1982. A comparison of the fish populations and habitat in open and closed salt marsh impoundments in east-central Florida. N.E. Gulf Sci. 5:25-37.

Gosner, K. L. 1971. Guide to Identification of Marine and Estuarine Invertebrates. Wiley-Interscience, New York, N.Y.

Harrington, R. W. and E. S. Harrington. 1982. Effects on fishes and their forage organisms of impounding a Florida salt marsh to prevent the breeding of salt marsh mosquitoes. Bull. Mar. Sci. 32:642-666.

Harris, E. 1959. The nitrogen cycle in Long Island Sound. Bull. Bingham Oceanogr. Collect. 17:31-42.

Heinle, D. R. 1974. An alternate grazing hypothesis for the Patuxent estuary. Chesapeake Sci. 15:146-150.

Hopkins, T. L. 1977. Zooplankton distribution in the surface waters of Tampa Bay, Florida. Bull. Mar. Sci. 27:467-478.

Jeffries, H. P. 1962. Copepod indicator species in estuaries. Ecology 43:730-733.

Knatz, G. 1978. Succession of copepod species in a middle Atlantic estuary. Estuaries 1:68-71.

Lampitt, R. S. 1978. Carnivorous feeding by a small marine copepod. Limnol. Oceanogr. 23:1228-1231.

Mahoney, R. K., and R. A. Gibson. 1983. Phytoplankton ecology of the Indian River near Vero Beach, Florida. Florida Scient. 46:212-232.

Miller, R. J. 1974. Distribution and biomass of an estuarine ctenophore population, *Mnemiopsis leidyi* (A. Agassiz). Chesapeake Sci. 15:1-8.

Morista, M. 1959. Measuring of interspecific association and similarity between communities. Mem. Fac. Sci. Kyushu Univ. Ser. E., Biol. 3:65-80.

Nelson, T. C. 1925. On the occurrence and food habits of ctenophores in New Jersey inland coastal waters. Biol. Bull. 68:92-111.

Odum, H. T., R. P. Cuzon du Rest, R. J. Beyers, and C. Allbaugh. 1963. Diurnal metabolism, total phosphorus, Ohle anomaly, and zooplankton diversity of abnormal marine ecosystems of Texas. Publ. Inst. Mar. Sci. Univ. Texas 9:404-453.

Reeve, M. R. 1975. The ecological significance of the zooplankton in the shallow sub-tropical waters of South Florida. Pp. 352-371. *In:* Cronin, E. (ed.), Estuarine Research: Chemistry, Biology and the Estuarine System. Academic Press, New York, N.Y.

Rey, J. R., R. A. Crossman, T. R. Kain, and D. S. Taylor. 1986. An overview of impounded mangrove forests along a subtropical lagoon in east-central Florida, U.S.A. Pp. 341-350 *In:* Bhosale, L. (ed.), The Mangroves. Shivaji University Press, Kolhapur, India.

________, R. A. Crossman, T. R. Kain, F. E. Vose, and M. E. Peterson. 1987. Sampling zooplankton in shallow marsh and estuarine habitats: gear description and field tests. Estuaries 10:61-67.

________ and T. R. Kain. 1990. A Guide to the Salt Marsh Impoundments of Florida. Pub. Fl. Medical Ent. Lab. Vero Beach.

________, J. Shaffer, D. Tremain, R. A. Crossman, and T. Kain. 1990. Effects of re-establishing tidal connections in two impounded subtropical marshes on fishes and physical conditions. Wetlands 10:27-45.

Schooley, J. K. 1980. The structure and function of warm temperate estuarine fish communities. Ph.D. dissert., Univ. Florida, Gainesville.

Youngbluth, M., R. Gibson, P. Blades, D. Meyer, C. Stephens, and R. Mahoney. 1976. Plankton in the Indian River Lagoon. Pp. 40-60. *In:* Indian River Coastal Zone Study, 1975-1976 Annual Report. Harbor Branch Consortium, Ft. Pierce.

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LIGHT REQUIREMENTS FOR GROWTH OF MONOECIOUS HYDRILLA FROM THE POTOMAC RIVER

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Abstract: *Estimates, from laboratory and aquarium studies, were obtained of light compensation levels for the race of monoecious hydrilla* [Hydrilla verticillata *(L.f.) Royle] established in the Potomac River and of the effects of reduced light levels on plant growth and development. Results of this investigation indicate that hydrilla growth is retarded at Photosynthetically Active Radiation (PAR) levels below 100 μe/m²/sec. This is approximately equivalent to Secchi disc transparency, which is 5% of incident solar PAR. Our results suggest that depth and areal distribution of hydrilla in the Potomac River will be restricted to the limnetic zone. Growth should not occur below 1% of incident solar PAR, and probably will not occur below the 5% level.*

Since the initial discovery of a small colony of hydrilla in Dyke Marsh, VA in 1982 (Steward et al., 1984), the plant has continued to expand through the euphotic zone of the Potomac River shoreline both up and downstream from Dyke Marsh.

The maximum depth at which submersed plants will grow is normally determined by light penetration. This level has been defined as the compensation level and is that depth at which photosynthesis is balanced by respiration (Odum, 1971). For most submersed aquatic plants this level is where light intensity is 1% of the value received at the water surface (Hutchinson, 1975, p. 504).

Other than small losses due to scattered light, attenuation of PAR in water bodies is due to absorption. The major light absorption components are water, dissolved yellow pigments, photosynthetic biota (micro- and macrophytes) and inanimate particulate matter in suspension such as silt and clay (Kirk, 1983, p. 49).

Although other factors such as sediment composition, currents, and wave action may influence areal distribution of submersed plants, depth distribution is primarily controlled by light. It would be useful to know the approximate depth to which hydrilla could be expected to grow in order to more accurately predict the total potential area which could be colonized by the plant. It would also be helpful to estimate the impact of reduced light penetration from turbidity on growth and development of established colonies.

Studies were conducted in the laboratory and in outside aquaria to obtain estimates of light compensation levels for the race of hydrilla established in Dyke Marsh and to determine the effects of reduced light levels on growth and development of plants.

Methods and Materials—*Laboratory Studies*—Experiments were conducted using monoecious hydrilla, originally collected in Dyke Marsh on the Potomac River 3 miles South of Alexandria, VA and the Florida dioecious race. Germinated tubers were planted in a sandy loam substrate supplemented with 5% (v/v) composted cow manure and cultured in 18 l glass jars in pond water which was changed weekly. Temperature was maintained at 24 ± 2°C.

Lighting was provided by a combination of Gro-lux fluorescent lamps (GTE Sylvania Inc., Danvers, MA 01923) and incandescent bulbs under a 14 hr photoperiod. Values of incident light taken with a LI-COR Model LI-185B Quantum Radiometer/Photometer (LI-COR, Inc., Lincoln, Nebraska 68504) ranged from 50 μe/m^2/sec at soil level to 120 μe/m^2/sec at the water surface.

An infrared Gas Analyzer (IGA) system was used to determine the effect of light on the photosynthetic CO_2 fixation rates of the plants using the methods of Van and coworkers (1976) with minor modifications. We used an ADC-225-MK3 IGA and a Beckman Moniter II System O_2 analyzer. The system was otherwise identical to Van and coworkers (1976) except that two Florida or three Dyke Marsh plant fragments were used in 125 ml of 10 mM MES-NaOH, pH 5.5 and 5% (v/v) Hoagland's solution. Temperature was maintained at 30°C in a glass-sided water bath.

Aquarium Studies—These studies were conducted in outside aquaria 77 cm wide, 219 cm long and 65 cm deep. Water flow through the aquaria provided a complete volume change in 12 hours. Source and quality of the water supply was reported earlier (Steward, 1984) and has not changed. Desired light intensities were obtained by covering individual aquaria with various layers of commercial grade polypropylene shade fabric (Chicopee, Gainsville, GA 30503) that is used to reduce light transmission in glasshouses. Screen covers were fabricated by stapling various layers of shade fabric to frames constructed of 2.5 by 5 cm lumber. Attenuation of ambient PAR by the various covers was measured at different times of the day and expressed as "% Transmission of PAR", that is, screened PAR × 100/ambient PAR. Treatment levels therefore represent PAR values averaged over replicates and time. Measurements were obtained with a LI-190SB quantum sensor with a LI-185B integrating quantum photometer. The sensor was placed below the screens at a level corresponding to the water surface when aquaria contained water. Light measurements were also taken at various water depths in an unscreened aquarium using a LI-192SB underwater quantum sensor. These measurements estimated the amount of light absorbed by water.

A preliminary, unreplicated study was begun March 1987 to evaluate the feasibility of the experimental approach. Light treatments, as indicated in Table 1, were applied to plants placed in the outside aquaria. Measured responses, after 10 weeks growth, were sufficiently encouraging to warrant conducting a more comprehensive, replicated investigation. This second study was started July 6th and ended August 24th after 7 weeks growth.

Treatments consisted of four replicates of approximately 100, 65, 45, 22, 10, 5, 1 or 0.2% transmission of solar PAR. Each treatment replicate consisted of five 15 cm plastic pots planted with 2 germinated hydrilla tubers. Estimates were obtained of initial dry weight of germinated tubers. Ambient solar PAR was measured and recorded through the duration of the investigation using the LI-COR LI-550 printing integrator with the LI-190SB quantum sensor. The sensor was located on the laboratory building roof approximately 320 meters from the site of the experiments. Water was individually supplied and flowed continuously through each aquarium for the duration of the study.

At harvest, photographs were taken and measurements were obtained of the longest vertical stem and horizontal stolon in each pot. The number of individual stems were then counted and plants were separated into shoot and root portions which were dried at 60°C and then weighed. Data were analysed utilizing the ANOVA AND REG procedures of SAS (SAS Institute Inc., Cary, NC 27511).

RESULTS—*Laboratory Measurements*—The results of laboratory determinations of photosynthetic rates indicated that light compensation points, light required for half-maximal photosynthetic rates and for light saturation for monoecious and Florida dioecious races, were identical at approximately 10, 40 and 400 μe/m^2/sec respectively (Fig. 1). These values for dioecious hydrilla were lower than those reported earlier by Van and co-workers (1976) but comparable to those reported by Bowes and co-workers (1977).

Preliminary Aquarium Study—The full sun treatment (100% T) appeared to inhibit growth under the conditions of this study (Table 1). Biomass was higher at 22% and 9.5% T than at full sun but was reduced at 6.2% T. Reduced light intensities produced elongated shoots at all treatments below full sun. Production of new tubers was greatest at 9.5% T and decreased at

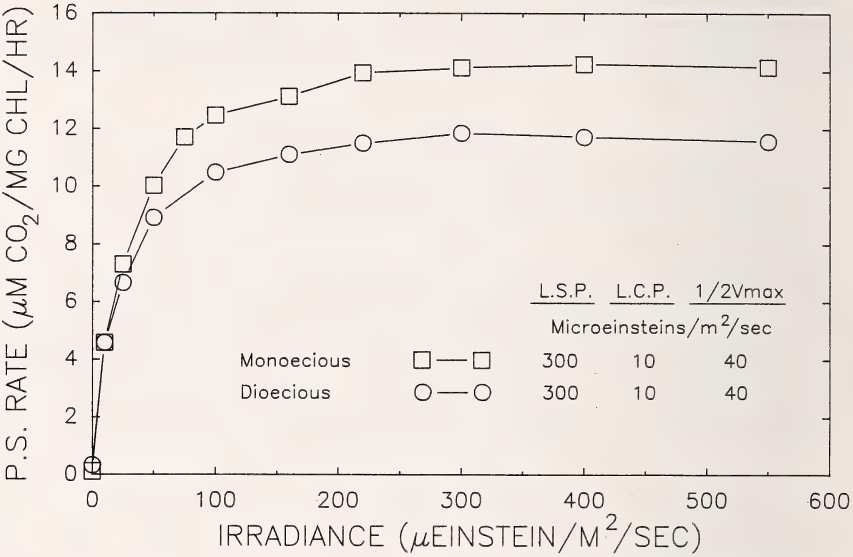

FIG. 1. The effect of light on the photosynthetic CO_2 fixation rate of apical stem sections of hydrilla grown in environmental chambers under light of 120 μe/m²/sec irradiance of PAR: at the light saturation point (L.S.P.); the light compensation point (L.C.P.) and light intensity required for half-maximal photosynthetic rate (1/2Vmax).

higher or lower light levels due perhaps to light inhibition or limitation. Full sun influenced rate of tuber development as indicated by greater numbers of mature tubers at this light level. The effect of light on structure of plant stands is apparent in the estimates of stem density (Table 1). High light (100% T) inhibited stem production and increased stolon production (measurements not taken). The lower light levels, below 9.5% T, provided distinctive growth patterns and reduced stem density. Very little growth occurred at 0.8 and 0.3% T.

Maximum sunlight over the period of this study averaged approximately 2000 μe/m²/sec. The light saturation level and light compensation points, as

TABLE 1. Hydrilla response to natural light of decreasing intensity after 10-weeks growth (12/3-21/5/87) in outside aquaria[1].

Light (% T)[2]	Biomass (gm)	Longest shoot (cm)	Immature tubers (No)	Mature tubers (No)	Stems[3] (No)
100	2.5c	24.5e	7.4c	4.4a	4.0c
22	4.7a	61.0d	8.2bc	1.6b	62.7a
9.5	3.9b	80.7b	13.4a	0.6c	62.3a
6.2	2.3c	85.7b	9.2b	0.1c	35.7b
0.8	0.3d	97.4a	4.0d	0.0c	9.3c
0.3	0.1d	72.9c	0.0e	0.0c	6.0c

[1] Means of one replicate from 9 pots per aquarium (except[3]) planted with two germinated tubers per pot. Means within columns with the same letter not different using Waller-Duncan test K ratio = 100.
[2] Percent transmission of solar PAR.
[3] Means of 3 pots.

previously mentioned, were determined in the laboratory to be 400 and 10 μe/m²/sec, 20 and 0.5% respectively of maximum full sun. The preliminary data fit these estimates in that growth optimums fell between these limits. The growth responses at 0.3% T were in accord with treatments below the light compensation level.

As mentioned before, treatments were not replicated. The variability between plants within treatments were used to estimate responses to treatments. Since plants and aquaria were randomly selected, it was assumed that experimental errors from these sources would be normally distributed and that large response differences between treatments were due to different light intensities. The results of this preliminary study demonstrated that experimental treatments produced light levels which inhibited growth of hydrilla. These findings were used to design the second more comprehensive study. The results of the second study validate the conclusions of the preliminary study and justify the selection of light treatment levels.

Replicated Aquarium Study—The average total daily ambient PAR recorded over the period of the investigation was 39.4±1.7 E/m² or 782±34 μe/m²/sec for a 14 hr photoperiod (Fig. 2A). A typical distribution of radiation through the day is shown for day 5 (Fig. 2B) with PAR_{max}. . .approximately 1917 μe/m²/sec from 12:00 to 15:00.

The average percent transmission of ambient light through the aquarium covers, and equivalent PAR values at the water surface, are shown in Table 2. The amount of light reaching the bottom of the aquaria was decreased additionally by passage through water in the aquaria (Fig. 3A,B). Light received at the tops of the pots (34 cm depth) containing germinated tubers was approximately 44% of the amount at the surface, that is, a 56% reduction of the amount passing through the screens and striking the water's surface. The amount of light received by developing plants in the early stages of growth averaged approximately 0.1, 0.5, 2, 4.5, 9.6, 19, 28 and 44% of the ambient solar PAR, i.e. 44% of the treatment levels. As plants which received sufficient light grew toward the water surface, the availability of light increased.

Statistical analysis (ANOVA) of the experimental data indicated that growth responses of hydrilla were significantly affected by light treatments. The effects of light on weight appeared straightforward, in that increased light intensities caused weight to increase. The estimated initial dry weight of germinated tubers was 0.074 grams. The change in grams of dry weight biomass was estimated to be 14a, 13a, 12a, 10b, 4c, 0.3d, −0.05d and −0.07d for 100, 65, 45, 22, 10, 5, 1 and 0.2% T treatments (mean weight changes with the same letter not different using Waller-Duncan Test, K ratio = 100). The loss of weight produced by the 0.2 and 1% T treatments and the nonsignificant change in the 5% T treatment indicates the plants were exposed to light below the Light Compensation Point (LCP). Biomass was increased by the 10% T treatment indicating that the LCP occurred between the 5 and 10% T treatment levels (92-206 μe/m²/sec, Max.). These findings are in agreement with those of Bowes and co-workers, 1977. They suggest that long term light compensation points are higher than those derived short term in the laboratory because they incorporate all parts of the plant includ-

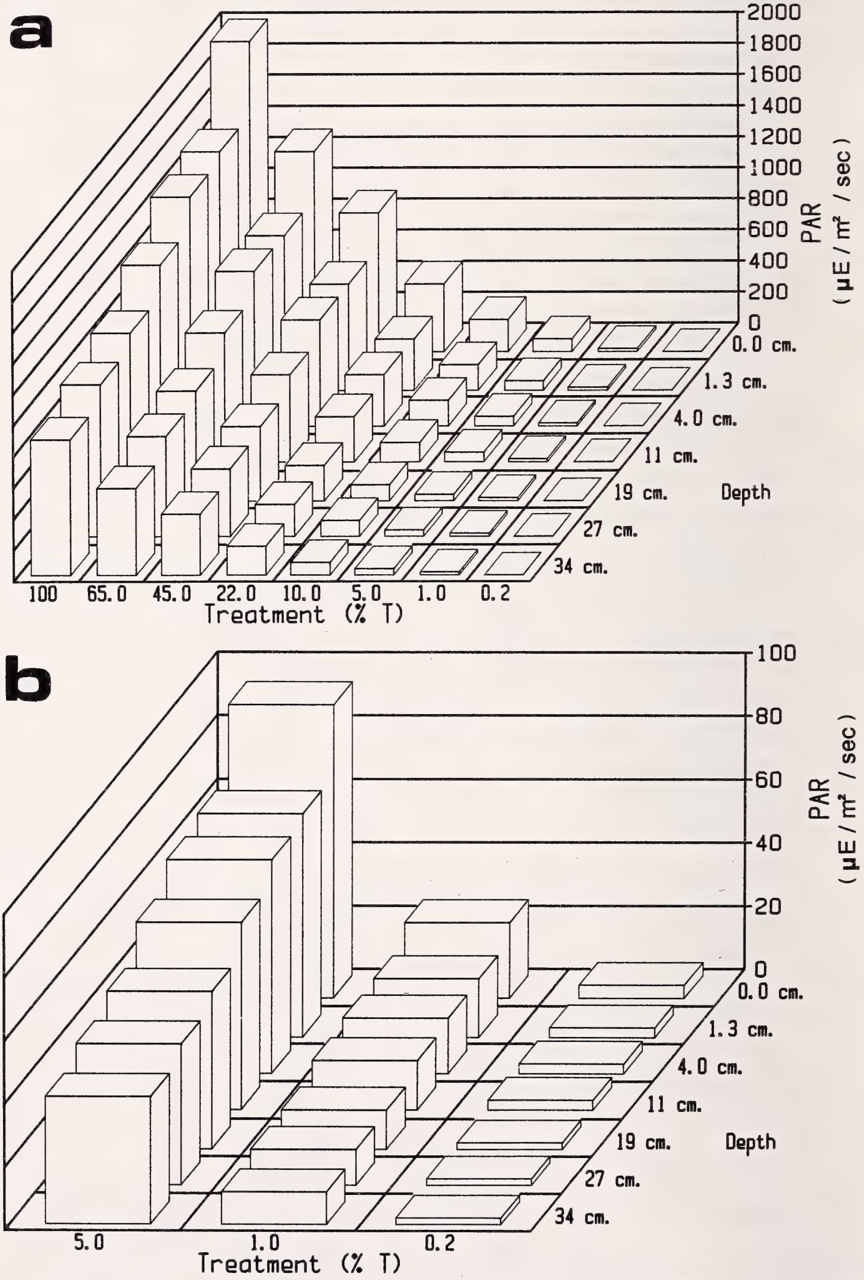

FIG. 2. Incident solar PAR radiation received at the site of the experiments: Ft. Lauderdale, FL 26° 05′N, 80° 14′W throughout the period of study: 9/7-25/8/87 (data are missing for 3,4/8/87), (A) and for day 5 (B).

ing the non-photosynthetic root tissues and a period (10-hr) of dark respiration each day.

The effect of light on elongation of shoots and stolons and on shoot production seemed more complex however, than effects on biomass. These data were subjected to regression analyses to determine the relationships of growth

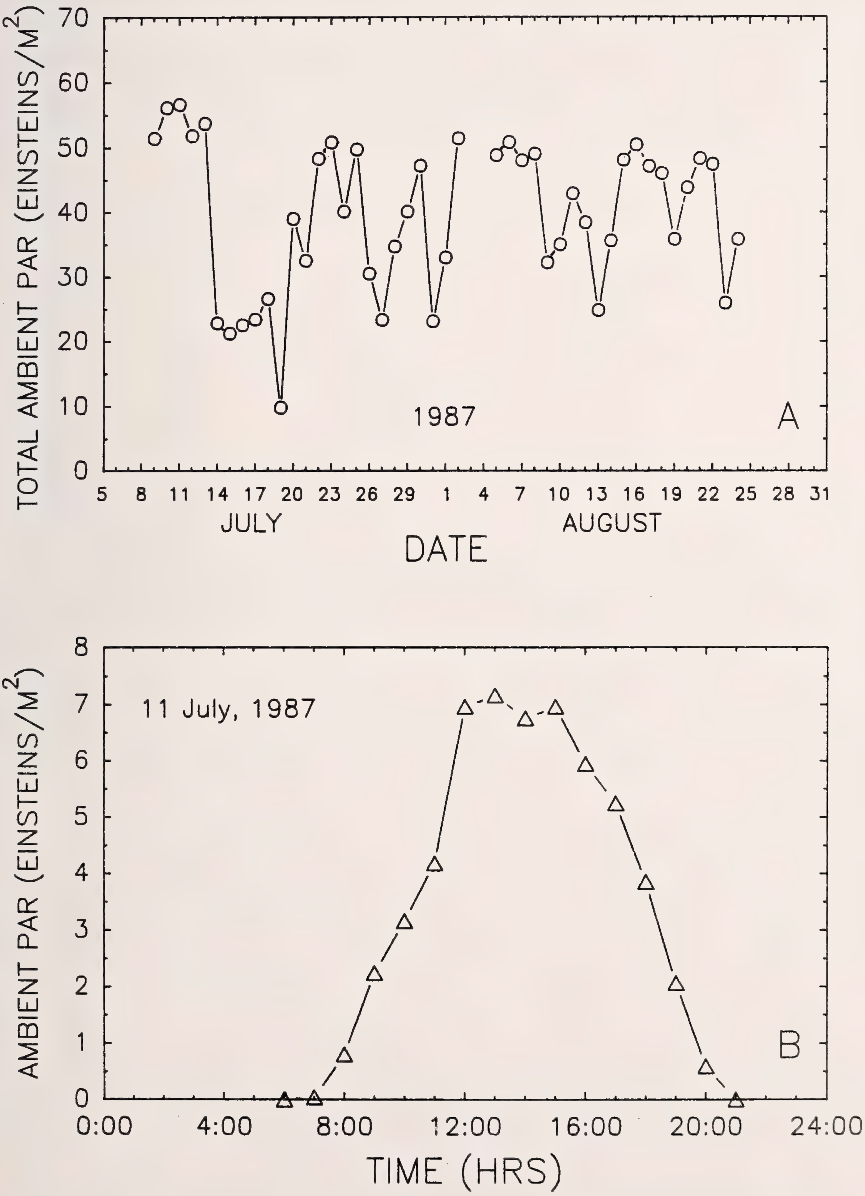

FIG. 3. The effect of shade fabric and water depth on transmission of solar PAR in outside aquaria (A). Expansion of scale for lower level light treatments (B).

responses to light treatments. The curvilinear relationships between light and weight change is illustrated in Fig. 4A. The calculated LCP, derived from the regression equation describing biomass change response to light, was 0.5%. This corresponds to 40 and 100 μe/m²/sec for PAR_{ave}...and PAR_{max}...respectively (Table 2). This value however appears to underestimate the effective LCP obtained experimentally since, as mentioned above, the 1% T treatment produced a negative weight change. The plotted relationship indicates that plant weight approached a maximum at approximately the 80% treatment level and then declined. Shoot production increased linearly at lower light intensities, and with increasing light reached a maximum at approximately the 75% treatment level then declined (Fig. 4B).

TABLE 2. Transmission of solar PAR through differently rated shade fabrics, alone or in combination.

Treatment	Shade fabric[1]	% T[2]	PAR_{ave}	PAR_{max}
0.2	92 + 92 + 73	0.2±0.1	2	4
1.0	80 + 80 + 30	1.2±0.3	9	24
5.0	92 + 51	4.6±0.4	36	92
10.0	73 + 51	10.3±1.0	81	206
22.0	73	22.0±1.2	172	440
45.0	51	44.5±2.3	348	890
65.0	30	64.9±2.8	508	1298
100.0	0	100	782	2000

[1] Manufactuers rating as % shade.
[2] Mean percent transmission of ambient PAR of 4 replications, with standard errors, averaged over time.

The relationship between light and stem or stolon length was not readily described as linear or curvilinear since, up to a 5th order polynomial, no line provided a reasonable fit to the data. Little and Hill (1978, p. 195) pointed out that often with biological data,..."the relationship between 2 variables may be so complex that no single equation can suffice to describe the relationship." Since no single equation best expressed the light-stem length relationship, portions of the data were analyzed individually and the results are illustrated (Fig. 4C).

The data points between 0.2 and 5% treatment levels were best fitted to a first-order equation, and the remaining points were best fitted to a second-order equation. The linear growth response of stems at the lower light intensities appears to be photomorphogenetic. Stem growth was etiolated at the 0.2%, 1% and 5% treatments as evidenced by the elongated internodes observed at the time of harvest.

The red portion of the light spectrum (700 nm) is active in inhibition of stem elongation (Downs, et al., 1957; Weintraub and McAlister, 1942) and would account for the decline in stem lengths beyond the 5% treatment level. The wavelengths in the red portion of the visible spectrum are strongly absorbed by water (Kirk, 1983) and absorption increases with depth. Light of reduced intensity received by developing plants at the bottom of aquaria would be deficient in wavelengths in the 700 nm region. Light of this quality would promote stem elongation and, as intensity increased as stems approached the surface or through higher treatment levels, growth in length would be inhibited as a result of higher levels of red light.

The curvilinear relationship between stem length and light levels above the 5% treatment levels implies growth inhibition and indication of stress at the higher light levels. These effects are probably related to photosynthetic as well as photomorphogenetic activities. The effect of reduced light on stolon

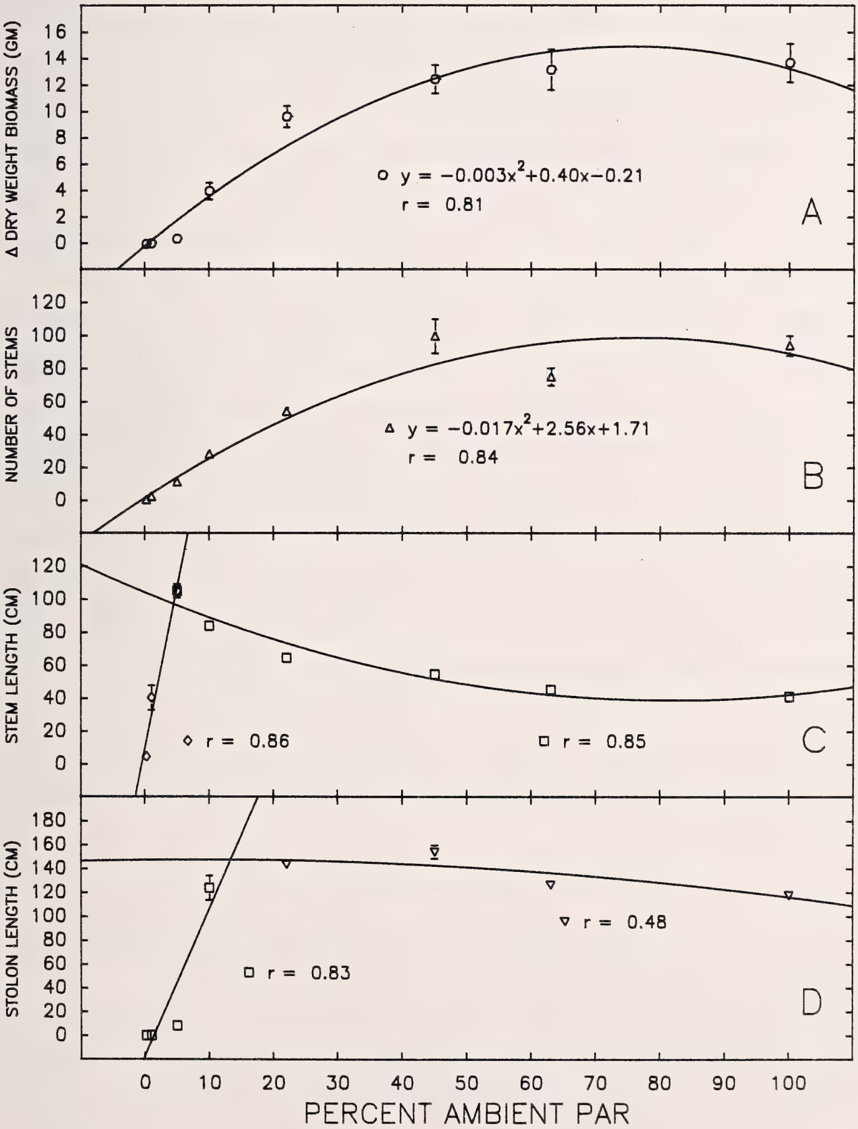

FIG. 4. Growth response of monoecious hydrilla in outside aquaria to natural light of varying intensity: A–Biomass, B–Shoot production; C–Shoot elongation and D–Stolon elongation.

length is similar to the effect on stem length (Fig. 4D). There was a linear increase in stolon length to the 10% treatment level and a curvilinear response beyond this level. The maximum response occurred at approximately 40% PAR and then length decreased, indicative of growth inhibition or stress at these higher light levels.

DISCUSSION—All measured growth elements, except stem elongation, were inhibited at light treatment levels below 5% transmission which corresponds approximately to Secchi disc transparency (Hutchinson, 1957, p. 403; Odum, 1971, p. 297). At higher light intensities, growth in all elements increased to optimum levels. Stem numbers and stolon length were at their maximum at the 45% transmission treatment level. Monoecious hydrilla, once established, expands its colonized area by extension of stolon growth along the hydrosoil surface. As the hydrosoil surface becomes more completely covered through increased stolon growth, stem production would increase and would result in increased plant density. Both of these growth elements are key indicators of nuisance growth levels of this aquatic weed.

Light treatment levels above 45% transmission decreased stolon growth, indicating that full sun inhibits and shading enhances stolon production, the spread of hydrilla and formation of dense stands of the plant. Self shading, resulting from increased shoot production, may, therefore, enhance and accelerate the colonization of new bottom areas. The plants' growth requirements and pattern indicates an ability to modify its environment by self shading to promote its areal expansion and dominance. Dry weight biomass increased with increasing light intensity. Regression analyses of dry-weight data estimated that weight would decrease at higher light intensities (Fig. 4A). However, growth response was at a maximum at the upper three treatment levels indicating a tolerance and ability to maintain biomass production at levels of full sun. Stem elongation was inhibited at high light intensities but this did not affect other growth elements. Stem elongation (etiolation) was enhanced at low light levels. Hydrilla growth appears to be retarded below Secchi disc transparency; however, if sufficient light penetration occurs to produce etiolation, plants may extend growth upward toward zones of higher light intensities.

An objective of this study was to develop information enabling determination of approximate depth limits for hydrilla growth. This limitation will be a function of light penetration and requires that measurements be taken *in situ* at various times throughout the growing season to relate light intensities to observed plant growth.

Laboratory determinations of light compensation and half maximum photosynthetic rates were 10 and 40 $\mu e/m^2/sec$, indicating a very narrow range over which photosynthesis and growth occur. Under the conditions of our aquarium studies, growth was retarded at or below the 5% light treatment level. Five percent of the daily average PAR was 39 $\mu e/m^2/sec$ at the surface and this value decreased with depth. At 5% of maximum full sun (2000 $\mu e/m^2/sec$), 100 $\mu e/m^2/sec$ PAR would have been available at the surface and approximately 44 μe/m^2/sec at the bottom due to absorption by water. Our results indicate that light levels greater than 100 μe/m^2/sec would be required to increase hydrilla growth rates.

A second objective of this study was to estimate the impact of reduced light penetration on growth and development of established hydrilla colonies. The most effective time for growth to be impacted should be in the spring in early developmental stages. The results of the preliminary study (Table 1) provide estimates of effects of reduced light on spring growth since the study was begun in March. Tuber production was retarded at 0.8 and 0.3% light treatment levels, indicating that regrowth potential from the propagules would be reduced at lower light levels. Biomass and stem density were also reduced by low light levels. If conditions of reduced light (i.e., at or below the light compensation level) could be maintained for a period sufficient to deplete the stored reserves of the propagules, new growth should be prevented or severely retarded.

Growth appeared to recover at 6.2% light treatment levels indicating a very narrow range between inadequate light levels and levels which produce increasing growth. It is noteworthy that Johnstone and Robinson (1987) reported that depth distribution of hydrilla and *Elodea canadensis* was reduced from 6.7 m and 4.6 m to 1.8 m in New Zealand's lake Tutira as a result of decreased light penetration. Increased turbidity from heavy rainfalls reduced the depth receiving 5% of surface PAR from 5.2 to 1.8 m. Plant growth below the 5% PAR depth was eliminated after 1 month for over 3 months, but plants regrew rapidly when water clarity was restored.

The results of this present study indicate that growth of monoecious hydrilla might be inhibited or possibly eliminated below the 5% PAR depth. Field studies should be conducted in the Potomac river to determine the plants' depth distribution in relation to light penetration and to evaluate the validity of these experimental findings.

ACKNOWLEDGMENTS—My thanks to Paul Madeira for his able assistance during the conduct of this work. This was a cooperative investigation between the U.S. Dep. Agric., U.S. Dep. Interior, Nat. Park Serv. interagency agreement IA-3040-6-8001, Univ. Florida, Agric, Res. Educ. Ctr., Fort Lauderdale, FL. Publ. as Journal Series No. R-00257 of the Florida Agric. Expt. Station.

LITERATURE CITED

BOWES, G., T. K. VAN, L. A. GARRARD, AND W. T. HALLER. 1977. Adaptation to low light levels by hydrilla. J. Aquat. Plant Manage. 15:32-35.

DOWNS, R. J., S. B. HENDRICKS, AND H. A. BORTHWICK. 1957. Photoreversible control of elongation of pinto beans and other plants under normal conditions of growth. Bot. Gaz. 118:199-208.

HUTCHINSON, G. E. 1957. A Treatise on Limnology. Vol. 1 Geography, Physics and Chemistry. John Wiley & Sons, Inc., New York, NY, p. 403, 424.

________ 1975. A Treatise on Limnology. Vol. 3 Limnological Botany. John Wiley & Sons, Inc., New York, NY, p. 504.

JOHNSTONE, I. M. AND P. W. ROBINSON. 1987. Light level variation in Lake Tutira after transient sediment inflow and its effect on the submersed macrophytes. New Zealand J. Mar. Freshwat. Res. 21:47-53.

Kirk, J. T. O. 1983. Light and Photosynthesis in Aquatic Ecosystems. Cambridge University Press, Cambridge, U.K., 401 pp.

Little, T. M. and F. J. Hills. 1978. Agricultural Experimentation Design and Analysis. John Wiley & Sons, New York, NY, 350 pp.

Odum, E. P. 1971. Fundamentals of Ecology. W. B. Saunders Company, Philadelphia, PA, p. 297.

Steward, K. K. 1984. Growth of hydrilla *(Hydrilla verticillata)* in hydrosoils of different composition. Weed Sci. 32:371-375.

_________, T. K. Van, V. Carter, and A. H. Pieterse. 1984. Hydrilla invades Washington, D.C. and the Potomac. Amer. J. Bot. 71:162-163.

Van, T. K., W. T. Haller, and G. Bowes. 1976. Comparison of the Photosynthetic Characteristics of Three Submersed Aquatic Plants. Plant Physiol. 58:761-768.

Weintraub, R. L., and E. D. McAlister. 1942. Developmental physiology of the grass seedling. I: Inhibition of the mesocotyl of *Avena sativa* by continuous exposure to light of low intensities. Smithson. Inst. Misc. Coll., 101:1-10.

Florida Scient. 54(3/4): 204-214. 1991.
Accepted: January 15, 1991.

Predation on Hatchling Diamondback Terrapin, *Malaclemys terrapin* (Schoepff), by the Ghost Crab, *Ocypode quadrata* (Fabricius)—*Rudolf G. Arndt*, Faculty of Natural Sciences and Mathematics, Stockton State College, Pomona, NJ 08240, USA

ABSTRACT: *The observation of a ghost crab catching and feeding on hatchling diamondback terrapin in the wild is the first record of an invertebrate predator on the terrapin. Ghost crabs readily fed on injured and dead hatchlings in captivity. The ghost crab and the terrapin are sympatric and syntopic. The ghost crab could be an important predator on hatchling terrapin.*

FALES (1976) stated that the ghost crab, *Ocypode quadrata,* is both a scavenger and an active predator which prowls the sea wrack left by the tide, especially at night. It feeds on a range of dead and live prey: dead fish (Fowler, 1911; Williams, 1965; Fales, 1976), amphipod beach fleas (Fowler, 1911), mole crab (Fales, 1976) and newly-hatched tern chicks (Sprunt, 1948). In North Carolina, more than 90% of food was of live prey, principally mole crab and coquina clam, but it included conspecifics, other crabs, amphipods and insects (Wolcott, 1978). The ghost crab is a major predator on the chicks and eggs of the piping plover in Virginia (I. W. Ailes, 1990).

OBSERVATIONS AND DISCUSSION—In midafternoon of 31 October 1990, on a low and sparsely vegetated foredune located some 6 m from the high tide line on the oceanside of Little Beach Island on the Edwin B. Forsythe National Wildlife Refuge, Atlantic County, New Jersey, I noted an adult ghost crab release its hold on a hatchling diamondback terrapin, *Malaclemys terrapin,* and attempt to escape. The crab was caught. Another hatchling was noted nearby at the entrance to a crab burrow, and a third was found in the lee of the dune. The first 2 turtles were bleeding from the head, while the third was uninjured.

Closer examination of the hatchlings on the next day showed that parts of the eyelids of both, as well as the nostril area and part of the upper jaw of 1, had been eaten away; the skin of a hind leg knee was also eaten off 1 turtle. Both turtles were lethargic. No sign of attack was found on the third hatchling. Turtle body weight range was 4.8 g to 5.2 g, and straight-line carapace length range was 27.3 mm to 27.6 mm. The live crab weighed 15.4 g and maximum cephalothorax width was 30.9 mm; it was then preserved.

Early on 3 November 1990, locomotor activity of 1 injured terrapin was still impaired, while the other was dead. They were then placed into individual 18.9 1 (5 gal) buckets each containing 1 adult ghost crab and deep beach sand. By that evening, the head, neck and all internal organs of both hatchlings had been consumed, as well as a front limb of the 1 alive earlier that day; both carcasses were on the sand surface. The carcasses were returned to the same containers. By the following morning no more of hatchling 1 had been consumed, while both the front limbs of the other hatchling had been consumed. One carcass was on the sand, while the other was in a crab burrow. While many mammals, birds and reptiles prey on the terrapin (Carr

1952, Ernst and Barbour 1972), no ghost crab, or any other invertebrate, has been recorded as a predator.

A terrapin nest was found at the base of the dune, ca. 0.5 m from where the uninjured hatchling had been found. The injured hatchlings were found 1.5 m and 2.7 m from the nest.

On 2 November, 4 crab holes nearest the sites of attack were excavated in a search for crab food remains. Two burrows each contained 1 adult crab, and a third was empty. The fourth burrow, at the entrance to which 1 of the hatchlings had been found, was empty. It was probably the crab from this burrow that had been caught previously while attacking a hatchling. No food remains were found in any burrow. Cut-open eggs of the piping plover were carried to and deposited at ghost crab burrow openings in Virginia (I. W. Ailes, 1990).

Along 0.4 km of dunes on the oceanfront of Little Beach Island were found 3 additional dunes on which fresh hatchling terrapin tracks intersected *Ocypode* tracks and ended. Also found with these crab tracks were tracks (listed in decreasing order of frequency) of rat (probably Norway rat, *Rattus norvegicus);* large species of gull, *Larus* sp.; red fox, *Vulpes fulva;* and raccoon, *Procyon lotor.* Presumably, individuals of one or more of these 5 genera preyed on these hatchlings.

In early November 1990, beach weather was sunny or mostly sunny, with a constant light to moderate wind, and with air temperatures that ranged to 18 °C and surface sand temperatures to 23 °C.

The range of the ghost crab, from Rhode Island to Brazil (Williams 1984), almost includes the entire distribution of the terrapin, from Cape Cod to southern Texas (Conant, 1975). In its range the ghost crab is the most terrestrial of the decapod crustaceans, and it is abundant along ocean beaches and sometimes on harbor beaches, often up to 0.4 km from the ocean (Williams, 1984). Fowler (1911) refers to the ghost crab as carnivorous, and Wolcott and Wolcott (1990) call it a voracious predator. These data suggest that predation on hatchling terrapin by the ghost crab could be a widespread and heretofore-overlooked important source of mortality on this turtle.

ACKNOWLEDGMENTS—I thank W. J. Smith for assistance in the field and him and G. M. Tilger for library help; J. D. Taylor and N. Sterling for information on local mammals; A. M. Teti and C. M. String for typing the manuscript; D. L. Beall, Manager, Edwin B. Forsythe National Wildlife Refuge, for permission to work on Little Beach Island; and 2 anonymous reviewers for helpful comments.

LITERATURE CITED

AILES, I. W. 1990. Management Biologist, U. S. Fish and Wildlife Service, Chincoteague National Wildlife Refuge, VA. Pers. comm.

CARR, A. F. 1952. Handbook of Turtles of the United States, Canada and Baja California. Comstock Publishing Associates, Ithaca, NY. 542 p.

CONANT, R. 1975. A Field Guide to Reptiles and Amphibians of Eastern and Central North America. Houghton Mifflin Co., Boston. 429 p.

ERNST, C. H. AND R. W. BARBOUR. 1972. Turtles of the United States. Univ. Press of Kentucky, Lexington, KY. 347 p.

FALES, R. R. 1976. Apparent predation on the mole crab *Emerita talpoida* (Say) by the ghost crab *Ocypode quadrata* (Fabricius). Ches. Sci. 17(1):65.

FOWLER, H. W. 1911. The Crustacea of New Jersey. Annu. Rep. N.J. State Mus., Trenton, N.J., pp. 29-651.

SPRUNT, A., JR. 1948. The tern colonies of the Dry Tortugas Keys. Auk 65(1):1-19.

WILLIAMS, A. B. 1965. Marine decapod crustaceans of the Carolines. Fish. Bull. 65(1):1-298.

________. 1984. Shrimps, lobsters, and crabs of the Atlantic Coast of the eastern United States, Maine to Florida. Smith. Inst. Press, Wash., D.C. 550 p.

WOLCOTT, T. G. 1978. Ecological role of ghost crabs, *Ocypode quadrata* (Fabricius) on an ocean beach: scavengers or predators? J. Exp. Mar. Biol. and Ecol. 31:67-82.

________ AND D. L. WOLCOTT. 1990. Wet behind the gills. Natural History, October:46-55.

Florida Scient. 54(3/4): 215-217. 1991.
Accepted: January 23, 1991.

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ADDITIONAL SECTION AWARDS FOR 1991

ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCES
(Outstanding Graduate Student Presentation)

Kermit Webb, Institute of Environmental Studies, Department of Chemistry, University of South Florida, "Implications of Copper in the Florida Environment."

ENGINEERING SCIENCES
(Outstanding Female Engineer)

Christine E. Kerschus, Department of Civil Engineering and Mechanics, University of South Florida, "Analysis of Culvert Performance Utilizing a Spreadsheet Program."

SPECIAL AWARDS

CENTRAL FLORIDA CHAPTER, THE EXPLORERS CLUB AWARD

Dennis Satterlee, Department of Anthropology, University of Florida, "Impact of El Nino Flooding on Prehistoric Agriculture in Southern Peru."

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AWARD

UNDERGRADUATE AWARDEES:

Kristin Varga, Department of Biology, University of Tampa, "Further Progress in the Purification of the Mate Recognition Pheromone from the Rotifer, *Brachionus plicatilis*."

Kevin C. McCarty, Department of Engineering and Mechanics, University of South Florida, "Hydraulic Control Structures for Wet Detention Systems."

HIGH SCHOOL AWARDEES (FLORIDA JUNIOR ACADEMY OF SCIENCE)
Matthew Carrigan, Satellite High School, Satellite Beach
Elizabeth DiNonno, Cardinal Gibbons High School, Ft. Lauderdale

UNIVERSITY OF FLORIDA CHAPTER, SIGMA XI AWARD

Louis C. Forline, Department of Anthropology, University of Florida, "Dietary Taboos: The Convergence of Cognition, Gender, Cultural Ecology, and Health Perspectives in a Brazilian Fishing Village."

FLORIDA INSTITUTE OF TECHNOLOGY CLUB, SIGMA XI AWARD

Michael P. Moses, Department of Physics and Space Sciences, Florida Institute of Technology "Development of a Hybrid Rocket Engine Prototype."

VICE ADMIRAL WILLIAM W. BEHRENS, JR./FLORIDA INSTITUTE OF OCEANOGRAPHY AWARD

Paloma Rodriguez, Department of Miami Sciences, University of South Florida, "Nitrogen Enrichment of Tampa Bay and Little Manatee River Phytoplankton Populations."

REVIEW

Lazell, James D., *Wildlife of the Florida Keys: A Natural History*, Island Press, Washington, D.C. and Covelo, California, 1989. Pp. xvi + 253. Price: $19.95, paperback.

THIS is the first book to attempt to treat the entire land fauna of the Florida Keys, although the emphasis is primarily on vertebrates.

The Introduction includes a good account of the geological history of the Keys in relation to the origin of the present land fauna and a concise description of the major vegetation associations of the Keys. Separate chapters are devoted to mammals, birds, reptiles, and amphibians. Individual accounts are given for all species of mammals, reptiles, and amphibians known from the Keys, with the exception of several that have been extirpated (black bear) or appear to have been escaped captives. Coverage of birds includes an annotated checklist of species recorded from the Keys and accounts of 12 "special species." Species accounts include information on taxonomy, distribution, habitats, and life history, as well as selected references. The accounts contain much new information on distribution, habitats, and various other aspects of life history and ecology resulting from the author's own work in the Keys. The accounts also reveal how much remains to be learned about the life histories of many species in the Keys. In the author's words, the treatment of land invertebrates is "fragmentary and eclectic." It includes some of the larger and more spectacular insects and other arthropods and tree snails. The book concludes with a brief "Overview," ranging over such disparate topics as biogeography of the Keys, an apparent trend toward inflation of the fronto-nasal region of mammals of the Keys and extreme south Florida, human population growth as the root cause of global environmental problems, the lack of rigorous science in conservation efforts, and the need for applying the general principles of natural selection to human evolution.

One criticism I have of the book is that it dwells too much on taxonomic details that are liable to be of little interest to the non-specialist reader seeking knowledge of the natural history of the Keys. In a number of cases, the author's taxonomic conclusions also lead to the use of scientific names that differ from those currently in general use, which is likely to be a source of confusion to the general reader.

Overall, however, this book is an important contribution to knowledge of the fauna of the Florida Keys and will undoubtedly receive wide use of professional biologists, students, land planners, governmental agencies, environmental organizations, and others with an interest in the remarkable fauna of the Keys and its preservation. Hopefully, this book also will serve as a stimulus for similar works on Florida's other distinctive biotic regions. — James N. Layne, Archbold Biological Station, P.O. Box 2957, Lake Placid, FL 33852.

REVIEW

Ronald L. Myers and John J. Ewel (eds.), *Ecosystems of Florida,* University of Central Florida Press, Orlando, 1990. Pp. xviii + 765. Price: Cloth, $75.00; paper, $29.95.

A FOREWORD by Marjorie Carr and the Preface by John Ewel provide a brief historical perspective of this book which encompasses the physical and biological setting of Florida. Having 18 chapters divided into five parts, the book begins with a discussion of climate, soils, and geology, proceeds through a narration of Florida vegetational and faunal associations, and ends with an interpretation of some of the problems related to the use and conservation of Florida's biological resources. A Reference section follows, containing over 2000 entries drawn from primarily journals, theses, and technical books, but including several agency reports as well. The book also possesses a useful Index together with lists of common and scientific names of over 700 organisms mentioned in the text.

Florida's ecosystems are arranged into 13 categories each treated in a single chapter beginning with upland systems (Pine Flatwoods and Dry Prairies, Scrub and High Pine, Temperate Hardwood Forest, South Florida Rockland), continuing through freshwater wetland systems (Swamps, Marshes, Lakes, Rivers and Streams), and finishing with coastal systems (Dunes and Maritime Forests, Salt Marshes, Mangroves, Inshore Marine Habitants, and Coral Reefs). This division necessarily lumps several communities in a chapter, and some discussions are general. Chapters on ecosystems range in length from 25 pages (Inshore Marine Habitants) to 52 pages (Dunes and Maritime Forests), and each is a commentary by specialists in the field upon a particular ecosystems' distribution in the state, its vegetational structure and composition, the physical characteristics of each ecosystem, and the role of stresses such as exotic species invasion. Faunal components of Florida's ecosystems are also discussed briefly in each chapter.

The editors have compiled considerable information on a vast and complex subject, and the resulting volume will serve newcomers to the state and beginning ecology students in Florida well. — Patricia M. Dooris, HDR Engineering, Inc., Tampa, FL.

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Environmental Sciences

ANALYSIS OF SELECTED TRACE METALS AND PESTICIDES OFFSHORE OF THE FLORIDA KEYS

RICHARD N. STROM(1), ROBERT S. BRAMAN(2), WALTER C. JAAP(3),
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ABSTRACT: *Trace metal and pesticide contents of sediments and producer and consumer organisms were analyzed from samples taken from 18 stations off the Florida Keys from Biscayne National Park to the Dry Tortugas. Samples were analyzed for total mercury, tin (inorganic and organic), arsenic (inorganic and methylated), lead, copper, cadmium, and halogenated pesticides. Pesticide concentrations were below detection limits. Observed ranges (as ppm) were: arsenic: <0.2 (sediments), 0-1.7 (producers), 0.1-2.2 (consumers); cadmium: 0.2-1.2 (sediments, <0.1-1.8 (producers), 0.7-22 (consumers); copper: 0.8-3.8 (sediments) 0.8-3.5 (producers) 1.5-38 (consumers); lead 0.8-4.5 (sediments) 1.0-4.9 (producers) 1.8-60 (consumers); mercury, <0.1 (sediments) <0.1 (producers), 0.02-0.4 (consumers); tin 0.002-0.2 (sediments), <0.08 (producers) <0.1-13 (consumers). In general, concentrations of trace metals increased from sediments to producers to consumers at each station. Though the concentrations tended to be low, some deviations were ascribed to human inputs. Fewer significant correlations were observed than expected possibly because of the dependence of the uptake mechanism upon the ability of the system (sediment, producer, consumer) to remove trace metals from particular materials. Sponges have this ability and may represent a useful means of monitoring the quality of the environment on a sustained basis. The results are generally consistent with a relatively clean environment with some localized anthropogenic effects.*

FLORIDA'S tremendous growth during the past two decades says much about the attractiveness of the state and its environment. Between 1970 and 1980, for instance, immigration accounted for more than 90% of Florida's population increase (Bucca, 1987). The increase in urbanization in Florida creates concern for the environment. This is especially true for the Florida

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Keys. This area contains North America's only tropical coral reef community a patch reef complex lying offshore from the Keys and extending over a distance of 220 miles from Key Biscayne to the Dry Tortugas (Fig. 1).

Until recently, many of the important coral reef areas of the world have been somewhat remote from heavy commercial development. Most of the stresses placed on the reefs have been the result of natural processes such as storms, fresh-water flooding, or warm water incursions onto the reef. In general, coral reefs appear to be well adapted to recover quickly from such natural stresses (Brown and Howard, 1985). Rapid commercial development of adjacent land areas has placed new stresses on the reefs to which they might not be well adapted. These stresses include increased turbidity, nutrient loading, pesticides and herbicides, and toxic metals. The effects of these added stresses are only poorly understood, but they could pose a serious threat to the viability of the coral reef ecosystem (Japp, 1984) found just a short distance off the Florida coast.

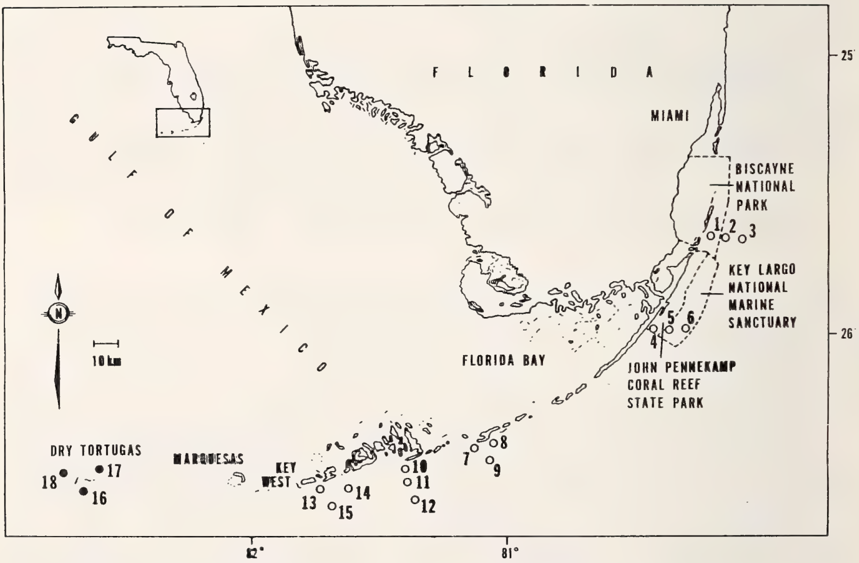

FIG. 1 Pesticide trace metal sampling stations (courtesy Florida Marine Research Institute)

The present study was undertaken as a cooperative effort between the Florida Marine Research Institute (FMRI), Florida Department of Natural Resources (FDNR), and the University of South Florida (USF). The purpose of the study was to assess the current levels of halogenated pesticides and toxic metals in the reef tract system.

MATERIALS AND METHODS—Samples of bottom sediment, and producer and consumer organisms were collected along with six transects (18 stations, Fig. 1) off the Florida Keys from Biscayne National Park (BNP) to the Dry Tortugas (exact locations are given elsewhere: Braman et al., 1989; Martin et al., 1990). The samples (sediment, producers, consumers) were analyzed for mercury (total), tin, arsenic (inorganic and methylated), lead, copper, cadmium, and halogenated pesticides.

Sample Collection—Sampling was conducted by FMRI divers during July 1988. Three replicate samples each of sediment and producer and consumer organisms were collected at each sample station. Sediment, consisting primarily of biogenic, calcareous sand was scraped from the unconsolidated surficial deposits. Algae and seagrasses were harvested by hand while sponges and *Palythoa* were harvested either by hand or using a small knife. Samples were placed in plastic bags under water, brought to the surface, dewatered, and placed in an ice chest. Collections from each station were placed in one large plastic bag and transferred to a freezer upon reaching shore. Samples were stored in freezers at several locations in the Keys. At the end of the collection phase, frozen samples were placed in ice chests with Dry Ice for transport to a walk-in freezer at USF.

Water samples (100 mL) were also collected at each station. Salinities were determined by a hand held refractometer, and surface-water temperatures were recorded for each station. Water samples were chilled, but not frozen, and salinities were redetermined using a conductivity meter at USF.

Sample Handling—Some 160 frozen samples were delivered to USF by the FMRI divers. These consisted of 54 samples each of bottom sediments, primary producers (*Thalassia testudinum* or *Halimeda* spp.), and consumers (sponges including Speciospongia vesparia, *Haliclona rubens, Xestospongia muta*, and a zoanthid, *Palythoa caribaeorum).* All samples were stored at USF in freezers until they could be prepared for analysis. Preparation consisted of homogenizing each sample and separating each into three portions for: (1) pesticide analysis; (2) atomic absorption analysis (Cd, Cu, and Pb); (3) DC spectrometry analysis (As, Hg, Sn);

Bottom sediments consisted primarily of well sorted sand-sized carbonate fragments of coral, *Halimeda* plates and shell material. The sediments were thawed, mixed, and subsampled. The subsets for pesticide analysis and DC spectrometry analysis were refrozen until analysis. The sediment subset for atomic absorption spectrophotometry (AAS) analysis was oven-dried at 60°C, reduced to a powder in an acid-cleaned ceramic ball mill, and stored in plastic bags.

Plant material was thawed, placed in 1000-mL plastic containers, covered with deionized water, and placed in al ultrasonic bath to remove adhering sediments and organisms. After allowing the sediment to settle, plants were rinsed and the rhizome or holfast structure removed. Only the leaves of *Thalassia* or upper portion of the algae *(Halimeda)* were analyzed. The plant material from each sample was mixed and subdivided. One portion was oven-dried and powdered. The main portion was refrozen.

Sponges were thawed, trimmed of adhering coral and sediments with surgical scissors, and subdivided as above. One portion was placed in a lyophilizer, freeze-dried and passed through a tissue chopper to reduce the size and to homogenize the sample.

Atomic Absorption Spectrometry Procedures (AAS)—All of the atomic absorption analyses were performed on a Perkin-Elmer model 403 AA spectrophotometer equipped with an HGA 2100 graphite furnace. Samples were prepared for analysis by dissolving in acid *(vide infra)* in Teflon-lined Parr bombs, and diluting. For the three types of samples—sediments, plants, and sponges—the dissolution procedures differed slightly and are described independently below.

Sample Digestion—Sediments—Approximately 20 g of oven-dried sediment was placed in a ceramic ball mill and reduced to silt-sized particles. Then 0.5 g of this material was weighed and placed in the Teflon liner of a Parr bomb. Hydrochloric acid (20%) was added until the carbonate dissolution reaction ceased. The volume of acid was reduced by gentle warming on a hot plate to near dryness. The sample was cooled, and 5mL of 50% nitric acid was added to oxidize any organics in the sediments. The Teflon liner was placed in a stainless steel Parr bomb, and heated in a 120°C oven for approximately 1.5 hours. The sample solution was cooled, the contents were transferred with deionized water to a 50-mL volumetric flask, and diluted to volume.

A slight residue of undigested material was left in each sample. This material was identified by petrographic microscopy and X-ray diffraction analysis and found to be primarily amorphous silica (opal-A) from sponge spicules, diatom frustules and minor amounts of quartz. A trace amount of gypsum was apparently formed during the dissolution procedure and was identified in the X-ray diffraction diagrams. No further effort was made to dissolve these residual materials. It was though that acide conditions in a Parr bomb and in the diluted sample solutions would leach any metals in the biogenic silica phase, and addition of HF would cause precipitation of calcium fluoride and loss of analyte due to co-precipitation.

Producers—Plant material, particularly *Thalassia*, was very resistant to acids. Approximately 0.5 g of oven-dried, powdered, plant material was placed in a Teflon liner and 20% HCl was added until the reaction with carbonate ceased (the *Halimeda* samples particularly contained significant amounts of skeletal carbonate). The volume of acid was reduced by evaporation and 5 mL of HNO_3 (69%) was added. The acid was again reduced by evaporation and 5 mL of HNO_3 and one mL of $HC10_4$ (92%) was added. The liner was placed in the steel jacket of a Parr bomb and heated at 120°C for 2 hours. After cooling, the solution was transferred to a 100 mL volumetric flask containing 10 mL of 5% monobasic ammonium phosphate solution and diluted to volume.

Consumers—Approximately 100 mg of freeze-dried sponge tissue was placed in a Teflon Parr bomb liner, and 5 mL of nitric acid (69%) added. The liner was placed in the stainless steel bomb and heated at 120°C for 2 hours in an oven. After cooling, the solution was transferred to a calibrated 10 mL test tube and was diluted to volume. As with the sediments, some samples contained insoluble opaline residues that were separated from the solutions by centrifugation.

The sample solutions described above were analyzed for cadmium, copper, and lead on the HGA 2100 graphite furnace using L'vov platforms and stabilized-temperature platform furnace methods for the more sensitive analytes and/or matrices.

Mercury Analyses—Sediments, consumers, and producers were analyzed for total mercury by the membrane-probe method (Braman, 1971; Braman et al., 1972). Methylated and inorganic mercury were reduced to elemental mercury by sodium borohydride in neutral pH solution. All mercury samples were corrected for matrix effects by using an internal standard. Blanks were found to be less than 5 ng mercury in all samples. The method has a detection limit near 0.01 ppm.

Sediment samples weighing 0.5-1.0 g were dissolved in 4 mL of 3 *M* HCl. One drop of bromthymol blue indicator and 40-50 mL of deionized water was added to this solution. This solution was adjusted to the blue color (pH above 4.6) of the indicator using ammonium hydroxide (6 *M*). Five drops of sodium borohydride were then added. The scanned Hg line response after 1-2 minutes was then the mercury response of the sample. A standard mercury sample was then added using a precision 0-25 µL syringe. The increased signal was due to the added standard and used to calculate the response of the mercury in the sample.

Consumer and producer samples did not require acide dissolution. These were weighed, grasses were cut up with a knife, and placed in the analysis beaker. Sodium borohydride reagent was added, as above, and analyte concentrations were determined.

Arsenic Speciation—This procedure is the same as that published previously (Braman et al., 1972) with modification dependent upon the sample type. Sediment samples weighing 10-500 mg (depending upon arsenic content) were dissolved in 2-5 mL of 3 *M* HCl and adjusted to pH 1-3 using sodium hydroxide with a methyl violet indicator. Samples were then transferred to a reaction flask. The "U" trap was cooled with liquid nitrogen and 2 mL of 2% sodium borohydride solution was added to the sample through the side port of the reaction chamber. The volatile arsines produced were carried out of the reaction chamber by the helium carrier gas and were frozen out in the U-trap over a five-minute period. Upon removing the liquid nitrogen, arisine was evolved followed by traces of carbon dioxide (if present) and then, in order, methyl arisine and dimethyl arsine. These gases were carried into a DC discharge detector with the spectrometer set on the 253.7 nm arsenic atomic emission line. Standard solutions of arsenic(III), methyl arsenic acid, and dimethylarsenic acid were used to calibrate response. The detection limit of the method was found to be approximately 2 ng.

Samples of consumers and producers did not require dissolution in acid and were weighed out and transferred to the analysis reaction chamber. 200-300 mg of solid oxalic acid was added to this chamber to maintain acidity pH 1-2. Subsequent analysis was identical to that of the sediment samples.

Tin Analysis Procedure—Tin was analyzed using the same apparatus and approximately the same procedure as for arsenic, except that the 250.7 nm tin emission line was used. Perchloric acide (72%) was used as the carbonate-dissolving acid to avoid a background of inorganic tin found in reagent grade hydrochloric acid. Tin is converted to stanane, methyl stanane, dimethyl stanane, and trimethyl stanane (if present) from its cationic forms by reaction in acid media with sodium borohydride. The detection limit of the DC discharge tin detector was approximately 2 ng/sample.

Pesticide Analyses—A subset of samples was sent to Envirolab, Ormond Beach, Florida, for analysis of EPA 608 chlorinated pesticides. Analyses were performed using standard procedures (EPA, 1983; Plumb, 1981), and identities of the pesticides were confirmed using gas chromatography-mass spectrometry (GC-MS).

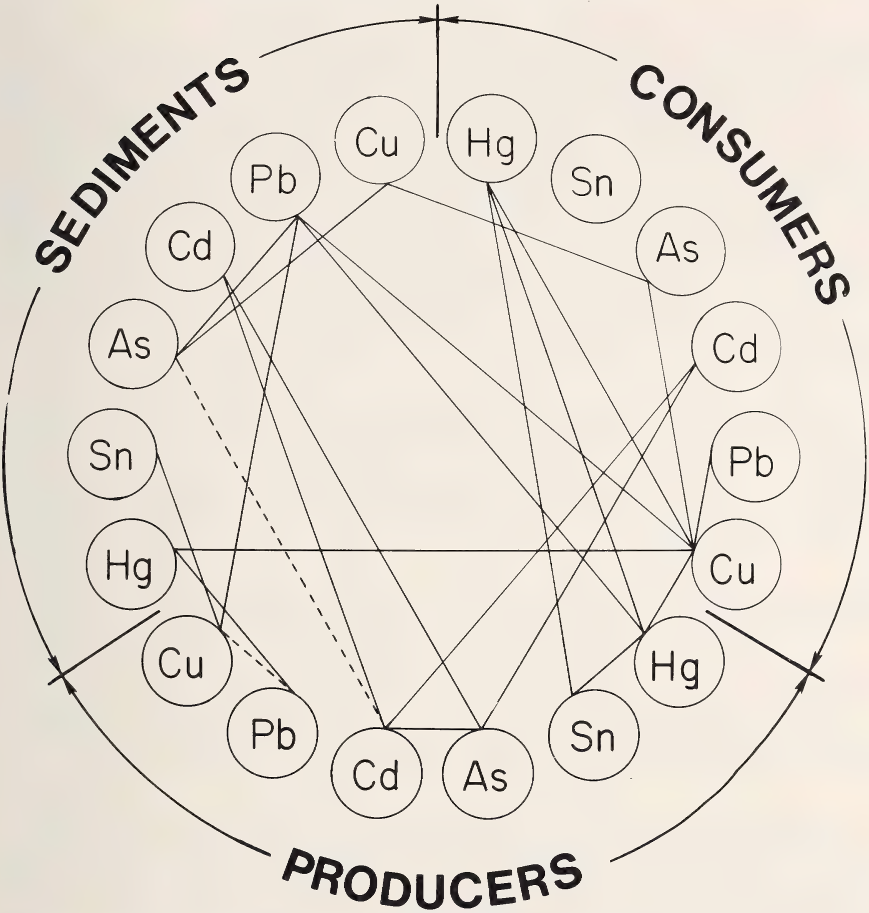

FIG. 2. Cluster showing relationship of correlated variables. Solid lines show positive correlations ($P<0.05$) and dotted lines show negative correlations (<0.05).

Data analysis—The data were subjected to a linear correlation analysis and the significant correlations were noted (Fig. 2).

In addition, the data were subjected to cluster analysis using three different methods: (1) all chemical data for all stations and all samples, (2) all chemical data excluding tin for producers (because the values were very low or were below detection limits for this element at many of the stations), and (3) all stations for copper concentrations only. Missing values were treated as the mean of other replicates. The analysis was performed using SIGTREE, which uses a bootstrap method (Efron, 1979; Diaconis and Elfron, 1983) to assess the statistical significance of two clusters linked at each stage of the cluster analysis. Full details of the program have been provided by Nemec and Brinkhurst (1987).

RESULTS AND DISCUSSION—Data on the samples and collection sites, and the results of the analyses of sediment, producer, and consumer samples for metals (copper, lead, cadmium, arsenic, ten, and mercury) and pesticides are presented in considerable detail elsewhere (Braman et al., 1989; Martin et al., 1990). The concentrations for six metals are summarized in Table 1.

Four trends consistently appear. First, most samples indicate a fairly pristine environment on the basis of generally low concentrations of metals. This was observed for all pesticide analyses of sediments, and for most samples for all metals. The exceptional areas were apparently anthropogenic inputs of metals and were detected as discussed below. Second, the concentrations of all metal species generally increased in the sequence sediment-producer-consumer. Third, there were few strong correlations (r^2=0.5 or more) between metal concentrations. Fourth, some analyses indicate the influence of localized sources of contamination or anthropogenic activities for cadmium, arsenic, and perhaps copper. The analysis of producers (grasses), presented a problem in obtaining a truly isolated monotypic sample. The results are, therefore, composite results, representative of the grasses and their epiphytic micro-community.

TABLE 1. Summary of combined trace metal content of samples

Sample		Metal, ppm[a]					
Type		Arsenic	Cadmium	Copper	Lead	Mercury	Tin
Sediment	Mean	0.0271	0.52	1.58	2.08	0.061	0.034
	Minimum	0.002	0.13	0.65	0.81	0.002	0.002
	Maximum	0.315	1.2	4.7	4.5	0.242	0.208
Producers	Mean	0.94	0.54	1.71	2.54	0.64	0.10
	Minimum	0.00	0.00	0.4	1.0	0.00	0.00
	Maximum	9.73	1.8	3.5	5.1	7.00	0.60
Consumers	Mean	0.71	5.48	9.01	11.08	0.091	1.77
	Minimum	0.03	0.7	1.5	1.3	0.002	0.1
	Maximum	6.6	22.0	38.0	60.0	0.434	13.1

[a]All samples calculated on a dry-weight basis.

Arsenic—Concentrations of three species of arsenic were obtained for each sample: inorganic arsenic, monomethylarsenic acid (MMA), and dimethylarsenic acid (DMA). Sediment samples consisted almost exclusively of inorganic arsenic, and the methylated forms were either present at levels that were below detection limits or at low concentrations. Dimethylarsenic acid (DMA) was frequently a considerable fraction of the total arsenic concentration in producer samples. The importance of methylated species was more evident for consumer samples because both monomethylarsenic acid and dimethylarsenic acid were present at detectable concentrations. Anthropogenic influences might explain notably higher arsenic concentrations in samples from Station 1 in Biscayne National park (BNP). Similarly, increased concentrations of monomethylarsenic acid and dimethylarsenic acid were noted in BNP samples (producer and consumer samples). Anomalous concentrations were observed for consumer samples from stations 4C and 16C (Hidden Harbor, Key Largo, and Bird Key Reef, Dry Tortugas.

Cadmium—Two distinct patterns were observed. First, concentrations generally increased in order: sediment, producers, consumers for a given station, although concentrations in sediments were low, and the difference in concentration between sediment and producers was not large. Second, geographical patterns or anomalies were observed: for example, cadmium concentrations near Seven Mile Bridge and New Found Harbor Key (stations 7,10,11) were quite high, compared with background values found with all other samples, and these anomalies probably represent localized, anthropogenic inputs of this metal.

Copper—Typical increase in concentrations occurred for the three sample types. Concentrations in sediments decreased moving offshore, generally, but this trend appeared to reverse in the lower Keys samples. A single significant copper correlation emerged from data averaged for a given station: copper in producers and lead in sediments ($r=0.53$, $P<0.05$).

Lead—Lead concentration in sediments was highest nearshore and toward the northern end of the Keys. This trend was most evident in two transects in the upper Keys (stations 1 to 3 and stations 4 to 6, BNP and Key Largo). Using all reasonable transition metal data (cadmium, copper, lead), it was found that lead in sediment was correlated with the concentration of copper in producers ($r=0.44$, $P<0.05$) and with the concentration of copper in consumers ($r=0.32$, $P=<0.05$); copper in producers was not correlated significantly with copper in consumers.

Mercury—Only small amounts of mercury were found in any sample. There is a possibility of a small increase in mercury in samples taken from stations 6 to 9. In any event, the amounts of mercury present were well below the crustal average concentration, 0.5 ppm (Mason, 1952). Seawater is known to be very low in mercury, levels less than 0.1 ppb (Fujita and Iwashima, 1981). This, and the absence of manufacturing activities in the area might account for the low concentrations of mercury observed.

Tin—All samples were analyzed for two species of tin, inorganic and organic. Only two sediment samples (2C and 3C) and three consumer samples (5B, 9C, and 10C) had any organo-tin compounds at detectable concentrations; none was detected in any producer samples. No obvious pattern between concentration of organo-tin and geographical location was noted. [It might be suspected of having an anthropogenic source, being used as an antifouling agent, as well as having agricultural uses.]

Pesticide Analyses—The results for pesticide analyses (EPA 608 chlorinated pesticides) for sediment, producers, and consumer samples were all below detection limits for a given matrix. For sediments, the detection limit was 0.5 µg/kg. For producers and consumers, the detection limit was 0.5 mg/kg. Because of the tenacity with which the organic pesticides were retained in these samples, the recovery levels were lower, and thus, the detection limits were higher. These results of course, imply nothing about higher members of the food chain.

Correlation Coefficients—A correlation matrix was obtained for all data (cadmium, copper, lead, etc.) and site-averaged data. Relatively few significant correlations ($p<0.05$) were obtained, and those that were obtained were usually weak ($r^2<0.50$) (Table 2). With the exception of cadmium, no significant correlations were observed for sediment concentration of a metal with

TABLE 2. Correlation matrix for all samples; data normalized to dry weights.

	CuSED	PbSED	CdSED	AsSED	SnSED	HgSED	CuPRO	PbPRO	CdPRO	AsPRO	SnPRO	HgPRO
CuSED	1.00											
PbSED	–0.05	1.00										
CdSED	–0.24	0.11	1.00									
AsSED	0.45	0.28	–0.14	1.00								
SnSED	0.03	–0.06	0.04	–0.01	1.00							
HgSED	–0.15	0.06	0.01	0.06	–0.13	1.00						
CuPRO	0.07	0.45	0.09	0.26	0.33	.00	1.00					
PbPRO	.00	–0.26	0.05	–0.25	0.09	0.35	–0.31	1.00				
CdPRO	–0.18	–0.11	0.30	–0.29	–0.03	–0.09	–0.15	–0.04	1.00			
AsPRO	–0.05	0.06	0.35	–0.22	–0.05	–0.05	–0.05	0.04	0.37	1.00		
SnPRO	–0.09	0.19	0.10	–0.31	0.16	0.15	0.27	–0.17	0.06	0.12	1.00	
HgPRO	–0.14	0.29	–0.12	–0.12	–0.12	0.15	–0.12	–0.15	0.06	.00	0.80	1.00
CuCON	0.12	0.32	–0.16	0.25	–0.13	0.36	0.15	–0.04	–0.03	–0.09	0.19	0.49
PbCON	–0.10	0.14	0.07	–0.01	0.08	0.04	0.05	–0.06	–0.16	–0.09	–0.01	–0.04
CdCON	–0.21	0.07	0.04	–0.05	–0.13	–0.20	–0.23	–0.19	0.47	0.42	–0.04	–0.12
AsCON	0.40	0.15	–0.24	0.22	–0.14	0.15	–0.13	–0.08	–0.12	–0.07	–0.03	0.18
SnCON	–0.14	0.03	0.21	–0.15	0.01	0.02	0.09	–0.22	–0.09	0.11	0.01	–0.14
HgCON	–0.11	0.41	–0.13	0.04	–0.14	0.20	0.16	–0.16	0.07	0.04	0.65	0.90
	CuCON	PbCON	CdCON	AsCON	SnCON	HgCON						
CuCON	1.00											
PbCON	0.28	1.00										
CdCON	–0.20	–0.14	1.00									
AsCON	0.37	–0.24	–0.09	1.00								
SnCON	–0.24	0.12	–0.10	–0.25	1.00							
HgCON	0.67	0.07	–0.16	0.25	–0.24	1.00						

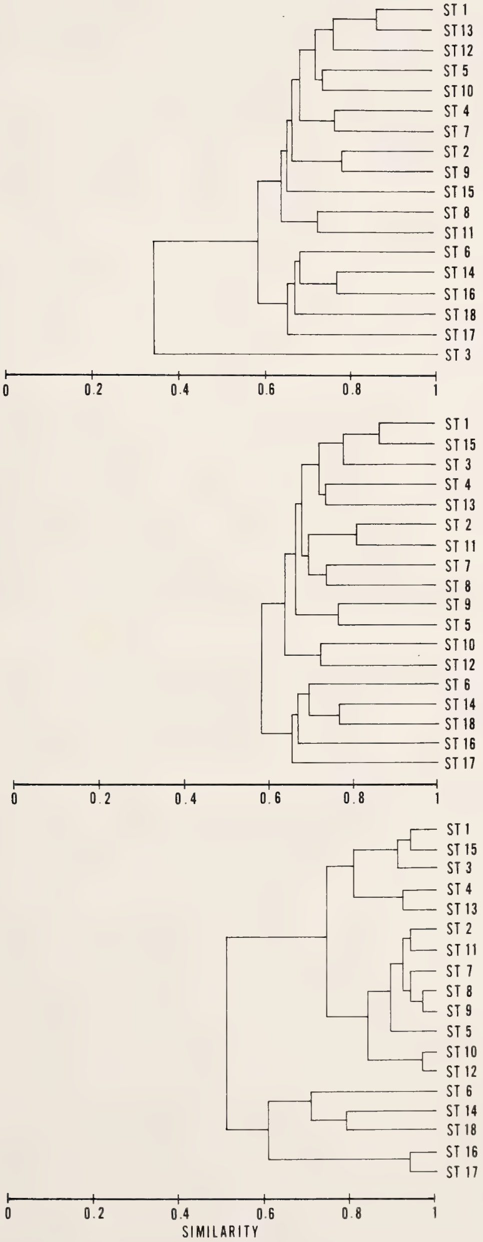

FIG. 3 Dendrogram linkages summarizing the results of classification analyses: top, all chemical data; middle, all chemical data, except tin; bottom, copper only.

producer concentrations of the same metal, and only two examples, cadmium and mercury, were found of significant correlations between producer and consumer concentrations for a given metal. Cadmium in sediments correlated directly (r=0.30) with producer cadmium that, in turn, related to consumer cadmium (r=ca. 0.5). Mercury in producers correlated with consumer mercury (r=0.90). Relationships are summarized (Fig. 2).

It might be argued that the limited number of correlations is a result of a high-energy environment. Uptake (or adhesion) depends upon the ability of a system (sediment, producer, consumer) to remove metal from particulate material. Sediments are largely unable to achieve this feat, but producers and consumers, especially sponges can.

Classification analyses were conducted to determine whether there were distinct patterns with respect to stations and contaminants. The dendrogramlinkages (Fig. 3a,b,c) were similar for all configurations (case a, all chemical data; case b, all chemical data, except in; and case c, copper only). The results indicate that there was no distinct pattern with respect to stations and contaminants. The probability analysis (Efron, 1979; Diaconis and Efron, 1983) rejected the hypothesis that the linkage and the clusters were significant. The P values (case a, 0.75-1.0; case b, 0.8-1.0; case c, 0.76-1.0) imply that the sites are very similar, lacking unique attributes that would set them apart. No inshore-offshore or Key Biscayne to Dry Tortugas gradient was detected. The dendrogram clusters (Fig. 3a-c) document the lack of patterns.

Previous studies of the investigated area have been limited in number. Three studies deserve mention because of their scope: 1) Mankar (1975) studied the distribution and concentration of mercury, lead, cobalt, zinc, and chromium in suspended particles and bottom sediment in the upper Florida Keys, Florida Bay, and Biscayne Bay. 2) Skinner and Jaap (1986) described a study involving some 19 stations in John Pennekamp Coral Reef State Park and Key Largo National Marine Sanctuary in 1985-86. Seasonal and spatial variations of aluminum, arsenic, copper, mercury, and lead as well as selected hydrocarbons, pesticides, phthalates, and PCBs were measured. Sediment and tissue samples of turtle grass *(Thalassia testudinum)* and the alga *Halimeda* spp. were analyzed; and 3) Glynn and co-workers (1989) examined the conditions of coral reef cnidarians from the northern Florida reef tract (*cf.* station 2, This Study).

There was more temporal variation in these three studies, and information is available for producers, but some producers *(T. testudinum)* showed greater tendency toward uptake of copper. That phenomenon was not observed with copper, nor with other trace elements in This Study. Skinner and Jaap (1986) reported a greater range of concentrations in producers for arsenic (0.5-3.9), for copper (6-33 ppm) for nearshore samples than was observed in the present study even for a similar time of the year. The results in the two studies for mercury were similar, though our lead analyses were lower (1-5 ppm vs. <10 ppm) for comparable times and samples. Results with cadmium (<3 ppm) and mercury (<0.1 ppm) were similar for both studies.

TABLE 3. Summary of comparisons with previous analyses of sediments from the same stations in different years

	As	Cd	Cu	Hg	Pb	Date
S/J Stations 12[a]	<0.5	<0.5	< 3	0.035	<5	7/1985
	<0.1	<0.05	12	<0.05	0.4	12/1985
	1.2	<0.1	4.5	<0.05	0.5	6/1986
	2.8	<0.2	2	<0.1	<1	6/1986
Station 2	0.10	0.46	0.88	0.11d	3.1	7/1988
S/J 20	1.3	<0.5	< 3	0.02	<5	7/1985
	<0.1	0.11	12	<0.05	0.8	12/1985
	0.3	<0.1	5	<0.05	<0.2	2/1986
	1.1	<0.2	2	<0.1	<0.1	6/1986
Station 5	0.077	0.40	1.6	0.20	1.5	7/1988
S/J/ Station 14	0.6	<0.5	< 3	0.045	<5	7/1985
	<0.1	<0.05	13	0.08	0.5	12/1985
	0.4	<0.1	3	<0.05	0.25	2/1986
		--------------Not available--------------				6/1986
Station 6	0.06	0.29	1.1	0.09	1.6	7/1988

[a] Skinner and Jaap (1986)

Our results were compared with those of Skinner and Jaap (1986) in Tables 3 and 4. There appear to be no significant differences for the sediment samples at three stations (Table 3). Comparisons among the consumer groups (Table 4) are a little more difficult because identical organisms were not sampled. Station 12/2 had one of two differences: mercury may have increased, copper decreased. At Station 20/5 probably lead and mercury increased. At Station 14/6 lead concentrations seem to have increased. Whether the increases reflect differences in uptake by different organisms is uncertain, and additional information is needed.

Our results (station 2) for consumers differ somewhat from those of Glynn and co-workers (1989), who examined scleractinian and octocoral samples. The arsenic, lead, and mercury did not differ within experimental error. Consumer cadmium (3.8±0.2 vs 0.16±0.01 ppm) and copper (24±6 vs 11.3±5 ppm) tended to be higher in our study.

Froelich and co-workers (1985) found that methyl arsenic acid (MMA) and dimethyl arsenic acid (DMA) were about 10% of the inorganic arsenic concentration in Charlotte Harbor. They found that MMA was being produced in phytoplankton blooms but that DMA was conservative. Their mass balance calculations indicated that all arsenic taken up by phytoplankters was converted to methylated species and returned to the estuary. MMA was converted comparatively rapidly, while DMA converted after a delay. These workers found the concentration of total dissolvable tin in the estuary to be between 10 and 75 pM (1-9 ppb) and was similar to other estuaries they had studied. Tin in Charlotte Harbor was associated with dissolved organic matter in an uncommon manner, perhaps because of the high concentration of organic matter found in the Peacer River. Byrd and Andreae (1982) summarized the estimated fluxes of tin into the environment. The concentrations of tin and methyl species were generally less than 50 pM (6 ppb) in rivers, estuaries, and surface and deep ocean waters. The vertical distribution of tin can be understood in terms of removal through particulate scavenging (Byrd and Andreae, 1982). These observations are in accord with the uptake of tin by the producers and consumer organisms described in This Study.

Table 4. Summary of comparisons with previous analyses of producers from the same stations in different years

	As	Cd	Cu	Hg	Pb	Date	Organism
S/J Station[a]	3.9	3	16	0.1	10	7/1985	*Halimeda opuntia*
	0.9	<0.3	9	<0.05	< 1	12/1985	*Halimeda* sp.
	0.3	0.3	16	0.1	1	2/1986	*Halimeda* sp.
	1.5	0.3	6	0.1	1		*Thalassia* sp.
	1.5	0.3	9	0.1	1	6/1986	*Thalassia* sp.
Station 2	0.4	0.38	2.3	0.89	2.0	7/1988	*Thalassia testudinum*
S/J Station 20	3.4	3	110	—	10	7/1985	*H. opuntia*
	1	<0.3	7	<0.05	< 1	12/1985	*Halimeda* sp.
	1.2	<0.3	8	<0.1	< 1	12/1985	*Thalassia* sp.
	1.3	<0.2	5	0.1	< 1	6/1986	*Halimeda* sp.
Station 5	0.80	0.37	0.97	1.13	3.8	7/1988	*T. testudinum*
S/J Station 14	0.5	3	7	—	1–	7/1985	*T. testudinum*
	2.8	<0.3	10	<0.05	< 1	12/1985	*Thalassia* sp.
	7.2	0.4	6	<0.1	< 1.	2/1986	*Thalassia* sp.
						2/1986	Not available
Station 6	0.75	0.33	1.8	0.09	4.7	7/1988	*T. testudinum*

[a] Skinner and Jaap (1986)

Our findings are significant for two reasons. First, the consumers (filter and suspension feeders) represent an upper trophic level and presumably reflect a high degree of bioaccumulation. Maximum concentrations of all elements including methylated species (MMA, DMA, organo-tin) were found in consumer samples. Second, consumers particularly sponges, should be studied regularly (as often as quarterly as a convenient means of monitoring the impact of environmental pressures from anthropogenic sources.

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LITERATURE CITED

BRAMAN, R. S. 1971. A membrane probe-spectral emission technique for mercury. Anal. Chem. 43, 1462.

BRAMAN, R. S., L. L. JUSTEN, AND C. C. FOREBACK. 1972. A direct volatilization-spectral emission type detection system for nanogram amounts of arsenic and antimony. Anal. Chem. 44, 2195.

———, D. F. MARTIN, AND R. N. STROM. 1989. Environmental Contamination of Coral Reefs, Final Report on Project 88-009 to Institute of Government, Tallahassee, FL (Copies on file in the Florida Legislative Library).

BROWN, B. E. AND L. S. HOWARD. 1985. Assessing the effects of "stress" on coral reefs. Pp 1-63. *In:* BLAXTER, J. S., F. S. RUSSELL, AND M. YONGE (eds.). Adv. Marine Biol., Vol. 22, Academic Press, London.

BUCCA, J. T. 1987. 1980-1986: More people moved in than out of every Florida county. Economic Leaflets 46 (6) 1-4.

BYRD, J. T. AND M. O. ANDREAE. 1982. Tin and methyl tin species in seawater: Concentrations and fluxes. Science 218:565-569.

DIACONIS, P. AND B. EFRON. 1983. Computer-intensive methods in statistics. Sci. Amer. 248 (5):116-130.

EFRON, B. 1979. Boostrap methods: another look at the jacknife. Ann. Statist., 7, 1-26.

ENVIRONMENTAL PROTECTION AGENCY. 1983. Methods for Chemical Analyses of Water and Wastes. EPA-600-14-79-020.

FROELICH, P. N., L. W. KAUL, TJ T. BYRD, M. O. ANDREAE, AND K. K. ROE. 1985. Arsenic barium, germanium, tin, disulfide and nutrient biogeochemistry in Charlotte Harbor, Florida, a phosphorus-enriched estuary. Esstuarine Coast. Shelf Sci. 20, 239-264.

FUJITA, M., AND K. IWASHIMA. 1981. Estimation of organic and total mercury in seawater around the Japanese archipelago. Environ. Sci. Technol., 15, 929-933.

GLYNN, P. E., A. M. SZMANT, E. F. CORCORAN, AND S. V. COFET-SHABICA. 1989. Condition of Coral Reef Cnidarians from the Northern Florida Reef Tract: Pesticides, Heavy Metals and Histopathological Examination. Unpublished report (Jan.), National Park Service, Contract No. CX 5280-5-1447, Department of the Interior.

JAAP, W. C. 1984. The ecology of the south Florida coral reefs: a community profile. U.S. Fish Wildl. Serv., Washington, D.C., 139 pp.

MANKER, J. P. 1975. Distribution and concentration of mercury, lead, cobalt, zinc, and chromium in suspended particles and bottom sediments, upper Florida Keys, Florida Bay, and Biscayne Bay. Ph.D. Dissertation. Rice University, Houston, Texas.

MARTIN, D. F., R. S. BRAMAN, AND R. N. STROM. 1990. Analysis of selected trace metals and pesticides in the Florida reef tract, J. Star Res. 17-35.

MASON, B. 1952. Principles of Geochemistry. John Wiley & Sons, Inc., New York.

NEMEC, A.F.L. AND R. O. BRINKHURST. 1987. Using the Boostrap to assess statistical significance in the cluster analysis of species abundance data. Can. J. Fish. and Aquat. Sci. 45, 965-970.

PLUMB, R. H., JR. 1981. Procedures for Handling and Chemical Analysis of sediment and Water Samples. Technical Report EPA/CE-81-1. Environmental Protection Agency/Corps of Engineers Technical Committee on criteria for Dredged and Fill Material. U.S. Army Engineer Waterways Experimental Station, CE, Vicksburg, MS.

SKINNER, R. AND W. C. JAAP. 1986. Trace metals and pesticides in sediments and organisms in John Pennekamp Coral Reef State Park and Key Largo National Marine Sanctuary. Report to the Florida Department of Environmental Regulation Coastal Zone Management Office. November.

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ESTIMATING POPULATION SIZE AND HATCHLING MORTALITY OF *GOPHERUS POLYPHEMUS*

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ABSTRACT: *The demography of gopher tortoises* (Gopherus polyphemus) *is poorly known. We excavated 1019 tortoise burrows and determined the size class distribution of a west-central Florida population of gopher tortoises. We captured 400 tortoises. Both very small juveniles and very large adults were poorly represented in this population, relative to intermediate sized individuals. The estimated annual mortality rate was 92.3% from nest-egg through the first year of life. Using the correction factor (0.614) frequently employed to estimate tortoise population size, results in an overestimate of this population by a factor of 1.4. We caution against the generic use of this correction factor to estimate tortoise population size and suggest using site- or habitat-specific correction factors.*

GOPHER tortoises *(Gopherus polyphemus)* inhabit uplands in six coastal plain states (Auffenberg and Franz, 1982). Tortoises excavate deep burrows that protect them and a suite of vertebrate and invertebrate fauna from extreme climatic conditions and predation (see Cox et al., 1987 and Jackson and Milstrey, 1989 for reviews). Because of the increasingly rapid human development of Florida upland habitats, gopher tortoise populations are declining and often are being relocated in an attempt to preserve this species (Auffenberg and Franz, 1982).

Gopher tortoise burrows can be categorized as active, inactive, or abandoned by the physical appearance of the entrance (Auffenberg and Franz, 1982). The intent of this scheme was to determine how recently a tortoise occupied a given burrow. Based on results of a long-term survey of 122 burrows in a single north Florida population (Auffenberg and Franz, 1982), a correction factor (0.614) was adopted by the Florida Game and Fresh Water Fish Commission to estimate population size from the total number of active plus inactive burrows on a site. This indirect method of estimating population size recently has been questioned (Cox et al., 1987; Burke, 1989) because of the high temporal and spatial variation in tortoise occupancy per burrow (Fucigna et al., 1989; Godley, 1989; Stout et al., 1989). Here, we compare the correction factor calculated from a west-central Florida population of tortoises with that reported by Auffenberg and Franz (1982). Additionally, we include demographic data for this central Florida tortoise population to evaluate size class structure, estimate hatchling mortality, and compare these data with those reported by Alford (1980).

METHODS AND MATERIALS—*Study Site*—This research was conducted on a 146 ha plot of sandhill habitat, that is surrounded by human development and located in Hernando County, west-central Florida (28° 30' N; 82° 30' W). Sandhill is characterized by well-drained, sandy soils, a sparse overstory, and dense grass ground cover (Laessle, 1958). Sandhill habitats are subject to intense, lightning-induced burns of varying frequencies (Williamson and Black, 1981; Mushinsky and Gibson, 1990). Turkey oak *(Quercus laevis)*, blue-jack oak *(Quercus incana)*, sand-live oak *(Quercus geminata)*, and long-leaf pine *(Pinus palustris)* were among the common trees at our study site. Persimmon *(Diospyros virginiana)* was found frequently in isolated monotypic stands. Wiregrass *(Aristida stricta)* was the dominant grass. Dog fennel (*Eupatorium* sp.), yucca *(Yucca filamentosa)*, saw palmetto *(Serenoa repens)*, sensitive plant *(Cassia nictitans)* and prickly pear cactus *(Opuntia humifusa)* were among the common herbaceous plants. We collected data from 5 July through 18 August 1989.

Burrow Excavation—All burrows were located by a thorough visual search of the study site. Six investigators, each spaced 3 m apart, searched the entire study area on foot in a grid by grid fashion. The location of each burrow was marked with plastic surveyor's flagging. Gopher tortoise burrows were classified as active, inactive, or abandoned (Auffenberg and Franz, 1982) immediately prior to our excavation. A polyvinylchloride (PVC) pipe (3 m length X 1.27 cm diameter) was inserted into the mouth of each burrow as far as possible to serve as a guide for subsequent excavation. The bulk of the excavation was conducted with a hydraulic backhoe. The backhoe operator began the excavation by removing soil from the roof of the burrow in approximately 2 m long increments of varying depths. The operator was assisted by an investigator equipped with a hand shovel who continuously fed the PVC pipe down the burrow. The cavity of the burrow generally was easy to follow because the soil at the roof of the burrow was less compact and differed in coloration. All burrows were excavated to the end or until sight of the burrow cavity was lost.

We recorded presence or absence of gopher tortoises for all excavated burrows. The number of tortoises captured was divided by the total number of active plus inactive burrows to determine a site-specific correction factor.

We recorded the sex of all adult tortoises. For each tortoise, we measured carapace and plastron lengths (CL, PL) to the nearest 1 mm and their mass to the nearest 1 g, prior to their removal from the site to the relocation destination. A histogram of size class frequencies was constructed using the scheme proposed by Alford (1980). Males less than 17 cm and females less than 22 cm CL were classified as juveniles, following the relocation reporting criteria of the Florida Game and Fresh Water Fish Commission.

Using Iverson's (1979) criteria of 23 cm minimum CL for reproductive females and an average of 5 eggs per female per year, we estimated mortality from egg laying through the first year of life. Our procedure for estimating mortality follows Alford (1980) and assumes both an equal sex ratio and a stable, age-specific mortality rate.

RESULTS—*Burrow Excavations and Tortoise Distribution*—We excavated 1019 burrows, 454 of which we classified active, 449 as inactive, and 116 as abandoned. Although all active and inactive burrows we located were excavated, time constraints prevented excavation of a small fraction of the abandoned burrows (< 5%). A total of 400 tortoises were captured which yielded a site-specific correction factor of 0.443 tortoises present per active plus inactive burrow.

Measurements of CL were available for only 372 tortoises as 28 individuals escaped from our holding pen. The size class distribution of CL (Fig 1) is non-normal and highly leptokurtic (G2=-0.829), reflecting the paucity of both very small and very large tortoises relative to intermediate-sized individuals. We found no tortoise less than 8.4 cm CL, and only two individuals greater than 31.8 cm CL. Eighty-five percent of all tortoises were between 12.0 cm and 28.2 cm CL. The modal carapace size class was 21.1-22.8 cm; mean CL was 19.6±5.6 cm. The average mass was 1332±925 g.

In estimating egg plus first year mortality, our assumption of an equal sex ratio was satisfied (99 males and 102 females) (Pearson chi-square=0.270, p=0.603). Our assumption of stable, size-class mortality remains untested as

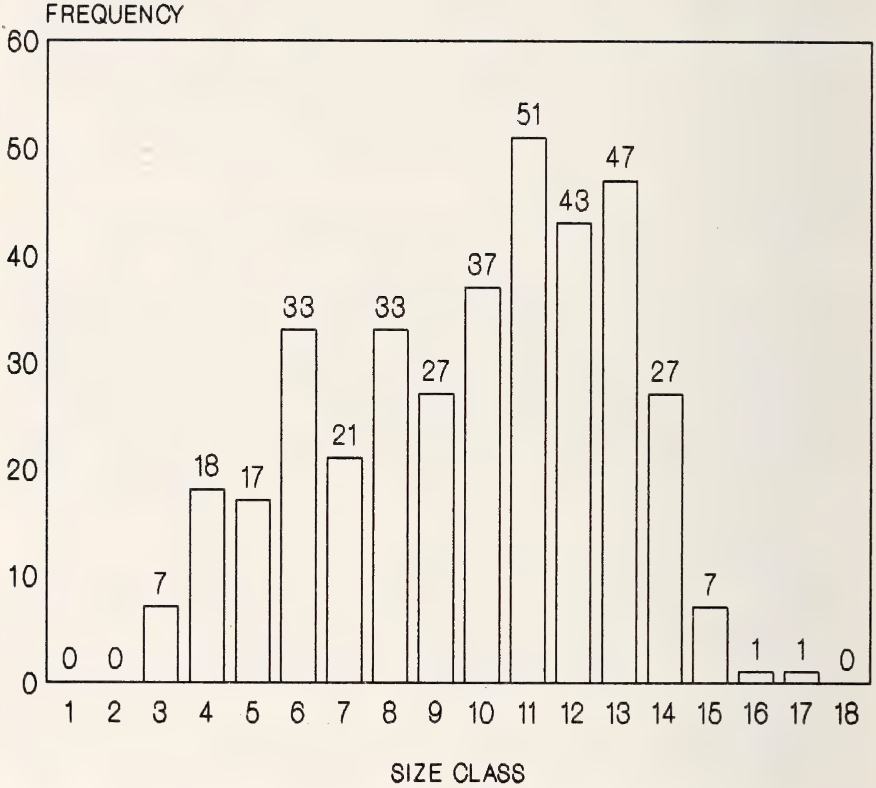

FIG. 1.-Distribution of carapace lengths of 372 gopher tortoises. Class designations follow Alford (1980) and indicate the following maximum CL (cm) in each class: 1-4.8; 2-6.6; 3-8.4; 4-10.2; 5-12.0; 6-13.8; 7-15.6; 8-17.4; 9-19.2; 10-21.0; 11-22.8; 12-24.6; 13-26.4; 14-28.2; 15-30.0; 16-31.8; 17-32.6; 18-34.4. Number above each bar represents # of individuals in each size class.

the duration of our study was only one season. Based upon the presence of fifty-eight females greater than 23 cm CL, we estimated an average annual egg production of 290 for this population. If we use the mean number of individuals in the size classes from 6.6-19.2 cm ($\bar{x}$=22.3) to estimate the average number of young surviving past the first year (Alford, 1980), we obtain a mortality estimate of 92.3% ([290-22.3]/290).

DISCUSSION—Many recent studies of gopher tortoises, including relocation projects, have relied upon classification of burrows by the physical characteristics of the entrance and application of a generic correction factor (0.614) to the total number of active and inactive burrows to estimate population size. Burke (1989) cautioned against use of a generic correction factor to estimate population size as correction factors have been shown to vary both between sites and within sites over time (Burke, 1989; Fucigna et al., 1989; Godley, 1989; Mushinsky and McCoy, 1991; Stout et al., 1989). Our calculated correction factor of 0.44 is based upon a total population count and thus supports Burke's call for site-specific correction factors to estimate tortoise population size. Use of the suggested correction factor of 0.614 at our study site would have overestimated the tortoise population by a factor of 1.4 (560 versus 400 tortoises).

Estimation of population size by the correction factor method requires careful assessment of the burrow category. Our experience indicates that individual researchers often differ in their classification of a given burrow. In the present scheme, an error in determining whether a burrow is active or inactive is not critical, as these burrow categories are combined to calculate the correction factor. Correct determination of inactive and abandoned burrows, however, is critical as the latter are not included in the correction factor. Burrows that are caved in several centimeters from the mouth should be categorized as abandoned because in this condition they are not readily usable by tortoises. Probing the burrow entrance to determine usability may help clarify its category. More detailed descriptions (e.g. Mushinsky and McCoy, 1991) of each burrow category may further reduce between-investigator error.

Both very small and very large individuals were represented poorly in this population relative to intermediate-sized individuals. Absence of hatchlings (up to 4.8 cm, Fig. 1) was not unexpected, as they typically do not emerge from the nest until late August (Iverson, 1979; Landers et al., 1980). The tendency of juveniles (up to 10.0-12.0 cm CL) (Landers et al., 1982), not to dig their own burrows, to share burrows with adults, or to conceal themselves under leaf litter (Auffenberg and Weaver, 1969; Douglass, 1978) may explain, in part, the apparent paucity of individuals in these smaller size classes. However, hatchling dispersal or, more probably, predation of eggs and hatchlings likely produced a real shortage of individuals in these size classes. Wilson and co-workers (1991) have shown that juvenile tortoises generally do not move long distances. Furthermore, Wilson (1991) documented considerable predation on tortoises less than 5 years old. Our data support Alford's contention (1980) that mortality may be most prevalent during the first year of a tortoise's life.

Several large burrows showed evidence of human disturbance. Human predation on adult tortoises is well documented (Auffenberg and Franz, 1982; Taylor, 1982), and may be one factor contributing to the lack of large adults at our study site. Kushlan and Mazzotti (1984), for example, documented " a relatively high proportion of larger, presumably older individuals" (25-35 cm CL) in a south Florida tortoise population which has been "free from human exploitation." Additionally, human predation on large adult females may affect demographic profiles by reducing the number of hatchlings available for recruitment into a population. Skewness of our size distribution may be a reflection of reduced growth rates with age and therefore an accumulation of similar-sized, larger adults in the population (Alford, 1980; Auffenberg and Iverson, 1979). Our casual observations support this hypothesis, as similar-sized individuals often differed in the number of plastral scute growth rings.

We suggest that if tortoise relocation projects continue, they should include demographic analyses. It would be of interest to determine the success of relocation for populations with relatively few versus many reproductively mature individuals. Populations with relatively few intermediate-sized, but mature individuals and large numbers of juveniles may be more susceptible to extinction. In such populations, efforts may be necessary to protect small individuals from predation until they reach reproductive age.

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LITERATURE CITED

ALFORD, R. A. 1980. Population structure of *Gopherus polyphemus* in northern Florida. J. Herp. 14(2):177-182.

AUFFENBERG, W. AND R. FRANZ. 1982. The status and distribution of the gopher tortoise *(Gopherus polyphemus)*. Pp. 95-126. *In:* BURY, R. B. (ed.), North American Tortoises: Conservation and Ecology. Wildl. Res. Rep. 12: U. S. Dept. Interior, Washington D. C.

————, AND J. B. IVERSON. 1979. Demography of Terrestrial Turtles. Pp. 541-568. *In*: HARLESS, M. AND N. MORLOCK (eds.), Turtles: research and Perspectives. John Wiley and Sons, Inc., New York.

————, AND W. G. WEAVER. 1969. *Gopherus berlandieri* in southeastern Texas. Bull. Fla. St. Mus. 13:141-203.

BURKE, R. 1989. Burrow-to-tortoise conversion factors: comparison of three gopher tortoise survey techniques. Herp. Rev., 20(4):92-94.

COX, J., D. INKLEY, AND R. KAUTZ. 1987. Ecology and habitat protection needs of gopher tortoise *(Gopherus polyphemus)* populations found on lands slated for large-scale development in Florida. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Tech. Rep. No. 4. Tallahassee, FL. 74 pp.

DOUGLASS, J. F. 1978. Refugia of juvenile gopher tortoises, *Gopherus polyphemus* (Reptilia, Testudines, Testudinidae). J. Herp. 12(3):412-413.

FUCIGNA, T. F., JR. AND D. K. NICKERSON, JR. 1989. Relocations of two groups of gopher tortoises from Palm Beach County to Martin County, Florida. Pp. 59-72. *In*: DIEMER, D. R. JACKSON, J. L. LANDERS, J. N. LAYNE, AND D. A. WOOD (eds.), Gopher Tortoise Relocation Symposium Proceedings. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report No. 5. Tallahassee, FL. 109 pp.

GODLEY, J. S. 1989. Comparison of gopher tortoise populations relocated onto reclaimed phosphate-mined sites in Florida. Pp. 43-58. *In*: DIEMER, J. E., D. R. JACKSON, J. L. LANDERS, J. N. LAYNE, AND D. A. WOOD (eds.), Gopher Tortoise Relocation Symposium Proceedings. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Tech. Rep. No. 5. Tallahassee, FL. 109 pp.

IVERSON, J. B. 1979. The reproductive biology of *Gopherus polyphemus* (Chelonia: Testudinidae). Amer. Midl. Nat. 103(2):353-359.

JACKSON, D. R. AND F. G. MILSTREY. 1989. The fauna of gopher tortoise burrows. Pp. 86-98. *In:* DIEMER, J. E., D. R. JACKSON, J. L. LANDERS, J. N. LAYNE, AND D. A. WOOD (eds.), Gopher Tortoise Relocation Symposium Proceedings. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Tech. Rept. No. 5. Tallahassee, FL. 109 pp.

KUSHLAN, J. A. AND F. J. MAZZOTTI. 1984. Environmental effects on a coastal population of gopher tortoises. J. Herp. 18(3):231-239.

LAESSLE, A. M. 1958. The origin and successional relationships of sandhill vegetation and sand pine scrub. Ecol. Monogr. 28:261-387.

LANDERS, J. L., J. A. GARNER, AND W. A. MCRAE. 1980. Reproduction of gopher tortoises *(Gopherus polyphemus)* in southwestern Georgia. Herpetologica 36(4):353-361.

————, W. A. MCRAE, AND J. A. GARNER. 1982. Growth and maturity of the gopher tortoise in southwestern Georgia. Bull. Florida State Mus. Biol. Sci. 27(2):81-110.

MUSHINSKY, H. R. AND D. J. GIBSON. 1990. The influence of fire periodicity on habitat struture. *In*: BELL, S. E., E. D. MCCOY, AND H. R. MUSHINSKY (eds.), Habitat Structure: The Physical Arrangement of Objects in Space. Chapman and Hall Ltd.

————. AND E. D. MCCOY. The status of *Gopherus polyphemus* on twenty State and federal lands in Florida. *In*: BURY, R. B. AND D. J. GERMANO (eds.), North American Tortoises: recent research and opportunities into the twenty-first century. U. S. Department of Interior. Fish and Wildlife Service. Wildlife Research Report, Washington, D. C. In press.

STOUT, I. J., T. J. NOONAN, R. E. ROBERTS, AND D. R. RICHARDSON. 1989. A comparison of results of three gopher tortoise relocations in central and southeast Florida. Pp. 15-42. *In*: DIEMER, J. E., D. R. JACKSON, J. L. LANDERS, J. N. LAYNE, AND D. A. WOOD (eds.), Gopher Tortoise Relocation Symposium Proceedings. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report No. 5. Tallahassee, FL. 109 pp.

TAYLOR, R. W., JR. 1982. Human predation on the gopher tortoise *(Gopherus polyphemus)* in north-central Florida. Bull. Florida State Mus. Biol. Sci. 28:79-102.

WILLIAMSON, C. B. AND E. M. BLACK. 1981. High temperature of forest fires under pines as a selective advantage over oaks. Nature 293(5834):643-644.

WILSON, D. S. 1991. Estimates of survival for juvenile gopher tortoises, *Gopherus polyphemus*. J. Herp. 25(3):376-379.

WILSON, D. S., H. R. MUSHINSKY, AND E. D. MCCOY. Home range, activity, and burrow use of juvenile gopher tortoises *(Gopherus polyphemus)* in a central Florida population. *In*: BURY, R. B. AND D. J. GERMANO (eds.), North American Tortoises: recent research and opportunities into the twenty-first century. U. S. Department of Interior. Fish and Wildlife Service. Wildlife Research Report, Washington, D. C. In press.

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CHEMICAL ANALYSIS OF UNIDENTIFIED PEABODY SAMPLE—

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ABSTRACT: *Infrared spectroscopic procedures annd qualitative chemical tests are used to obtain information concerning the chemical composition of a material possibly black coral or fossil bone found at an archaeological site.*

ANIMAL remains in the collection of E.H. Thompson from a tomb at Chichen Itza, Yucatan, housed at the Peabody Museum, Harvard University, included a rather glossy black solid cylindrical object 29mm in length. It was suggested that this material might possibly be black coral (Antipatharia). If this identification were correct, it would have interesting implications for the significance of this item to the Maya. The sea and certain of its products were important in Maya ritual and religious ideology (Hamblin, 1985). Moreover, true black corals generally occur at great depths (Barnes 1980; James and Ginsburg, 1979). They would not be likely to wash ashore often, and their collection would have been infrequent, potentially adding to their value.

MATERIALS AND METHODS—A portion of this material, weighing 106 mg and approximately 5 mm X 3 mm in size, was submitted to this laboratory for possible identification as black coral. A small piece (ca. 10 mg) of the sample was removed and placed in an enclosed steel vial containing a stainless steel bearing. The enclosed vessel was placed in a "Wig-L-Bug" (Wig-L-Bug, Cresent Dental Mfg. Co., Chicago, Il.) and shaken for 2 min. until completely pulverized. A 2-mg sample of the powdered material was removed from the vial, mixed with 200 mg of KBr in a mortar, then pressed in a KBr die at 20,000 pounds for two min. The KBr pellet was removed from the die and examined in a 5 PC Nicolet Fourier transform infrared spectrophotometer (FT-IR).

RESULTS AND DISCUSSION—The pertinent infrared spectral bands are listed in Table 1. The Peabody Museum sample was not in any way similar to an FT-IR spectrum of black coral sample obtained from the Smithsonian Institution, Washington, D.C.

The unknown sample spectrum had an absorption band at 3385 cm-1, indicative of a hydroxy (OH) group. Doublet bands at 1454 and 1417 cm-1

TABLE 1. Summary of FT infrared absorption bands cm^{-1} of Peabody Museum unknown and related samples.

Peabody Sample	Smithsonian Coral Sample	USF-Dept.Geology Fossilbone bone samp
3385 (B, S)	3302 (B, S)	3424 (B, M)
1597 (M)	1655 (S)	
1454 (D, S)	1541 (M)	1458 (D, M)
1417 " "	1442 (VW)	1419 " "
1037 (VS)	1379 (VW)	1036 (VS)
871 (W)	1325 (VW)	866 (VW)
603 (D, S)	1236 (W)	603 (D, S)
587 " "	619 (M)	563 " "

[a] Band intensities—VS, very strong; M, medium; W, weak; VW, very weak; D, doublet; B, broad

and 871 cm-1 show the presence of carbonate. Bands at 1037 cm-1 and the doublet at 603 cm-1 and 567 cm-1 demonstrate the presence of phosphate.

Additional qualitative analysis was performed on another portion of the sample. Two ml of 6 M HNO_3 acid was added to this sample (ca. 5mg). A great deal of fizzing occurred, indicating presence of carbonates. The solution was divided into two portions. In one portion, a white precipitate formed on the addition of potassium oxalate solution which demonstrated the presence of calcium ion. In a second portion, a yellow precipitate was formed on the addition of a few drops of ammonium molybate solution, proving the presence of phosphates.

Based on the infrared spectral data and the wet chemistry tests, the sample is therefore probably fossilized bone consisting mainly of calcium hydroxycarboapatite. The black coral gave negative qualitative tests using the above reagents for carbonate ions and calcium ions but positive results for phosphate ions.

The Peabody Museum FT-IR spectrum is similar to an FT-IR spectrum of fossil bone donated by the University of South Florida, Department of Geology.

This is an example of a methodological test for identifying samples of fossil bone, that cannot be visually identified. In this case, and in others, fossil bone is easily confused with coral (and other substances). A relatively simple procedure allows for accurate identification, i.e., of bone, even with wet chemistry alone.

As has been demonstrated, a relatively simple wet chemical procedure alone allows for a useful preliminary differentiation between fossil bone and black coral. Comparative specimens of black coral are not available at many institutions, and culturally modified (cut and polished) black coral would lack many of the diagnostic features described in biological reports. For that reason, it is worthwhile to use the IR method for identification of suspected black coral from archaeological contexts.

Acknowledgments—I would like to thank Dr. Rosemary Joyce, Curator, and the staff of the Peabody Museum for permission to test this archaeological specimen. Dr. S. Carr (Boston University) analyzed the faunal collection that included this specimen and brought it to my attention.

LITERATURE CITED:

Barnes, R. D. 1980. Invertebrate Zoology, 4th ed. W.B. Saunders Company. Philadelphia.

Hamblin, N. L. 1985. The Role of marine resources in Maya economy; a case study from Cozumel, Mexico. Pp 159-173, *In*: (Pohl, M., ed.) Prehistoric Lowland Maya Environment and Subsistence Economy. Papers of the Peabody Museum of Archaeology and Ethnology, Harvard Uni., Cambridge, MA.

James, N. P., and R. N. Ginsburg, 1979. The Seaward margin of Belize Barrier and Atoll Reefs. International Association of Sedimentologists, Special Publication 3. Blackwell Scientific Publ., Oxford.

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GEOMETRIES OF SELECTED COMPOUNDS OF THE TYPE [RCOCHC(NR')R"]2Ni

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ABSTRACT: This study describes the magnetic properties of nickel(II) chelates of Schiff-base derivatives of ß-diketones as a means of inferring their geometry. These compounds exist not as associated species (pseudo-octahedral structures) but as a paramagnetic (tetrahedral or distorted planar) of diamagnetic (planar) compounds. This geometrical isomerism is described for $[C_6H_5COCHC(NC_6H_5)CH_3]_2Ni$ and $[C_6H_5COCHC(4\text{-}ClC_6H_4N)CH_3]_2Ni$. Magnetic susceptibilities of these compounds are consistent with the shift in the planar to pseudo-tetrahedral equilibrium.

THE role of nickel(II) Schiff-base compounds as model systems for effecting dehalogenation has led to a continued interest in their structure and properties. A report on amine-exchange reactions between bis(N-n-butylsalicylidineiminato)nickel(II) and diamines called attention to the unexpected side reaction of dehalogenation of chloroform solvent (Olszewski and Martin, 1965). Subsequently, the kinetics of dehalogenation of chloroform by this system and a proposed mechanism were presented (Martin, 1975). The wider scope of this reaction was reported by Nahar and Mukhedkar (1981), who examined the effect of changing the central metal ion (Cu, Ni, Zn, Pd, Pt) and found the platinum(II) derivative to be the most effective for effecting dehalogenation. Subsequently, we examined amine-assisted versus metal chelate-assisted dehalogenation (Hewes and Martin, 1984).

Related Schiff-base derivatives of the type $[RCOCHC(NR')R'']_2Ni$ have not been as effective as expected in the dehalogenation of chloroform under similar conditions (Luschinski and Martin, 1990). Structural differences may be involved. Compounds of this type could exist as three types of structures: planar, pseudo-tetrahedral (distorted planar), or octahedral. The first two forms may be interconvertible (Cotton and Wilkinson, 1972; Holm and O'Connor, 1971). The octahedral form is found in the trimeric structure of nickel acetylacetonate (Bullen et al., 1965). Hseu and co-workers (1963) investigated the structure of compounds of the type $[RCOCHC(NR')R'']_2Ni$ through attempted resolution by chiral chromatography (D-lactose). Partial resolutions were achieved for several compounds, including $[CH_3COCHC(NH)CH_3]_2Ni$, which might not have been expected to be pseudo-tetrahedral as a consequence of steric distortion. Knorr and Ruf

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TABLE 1. Properties of compounds of the type [RCOCHC(NR)'R"]$_2$Ni

Compound	R	R'	R"	Melting Point°C Observed	Melting Point°C Reserved	Analyses C Calc	Analyses C Found	Analyses H Calc	Analyses H Found	Analyses N Calc	Analyses N Found	Method[c]	Magnetic Susceptibility 10^6xg	Magnetic Susceptibility μeff, BM
1	CH_3	H	CH_3	249-51	247-8[a]							D	-2.65	diamag
2	CH_3	$4\text{-}O_2NC_6H_4$	CH_3	276-78		52.99	53.08	4.45	4.31	11.34	11.08	E	ca. 0	diamag
3	C_6H_5	C_6H_5	CH_3	217-19	215-16[a]							E	4.79	2.45
4	C_6H_5	C_6H_5	CH_3	210-212.5	-------[b]	72.34	72.13	5.31	5.20	5.27	5.19	D	-0.181	diamag
5	C_6H_5	C_6H_5	C_6H_5	278-80	278-9[a]							E	8.70	3.73
6	CH_3	$2,6\text{-}(CH_3)_2C_6H_3$	CH_3	220.5-222	219-20[a]							E	-0.20	diamag
7	CH_3	$4\text{-}CIC_6H_4$	CH_3	239-241	-------[b]	55.55	55.23	4.66	4.70	5.88	5.74	D	-0.272	diamag
8	CH_3	$4\text{-}CIC_6H_4$	CH_3	240-241.5		55.55	55.35	4.66	4.64	5.88	5.92	E	0.288	0.57
9	CH_3	$4\text{-}CIC_6H_4$	CH_3	251-253	-------[b]	64.04	64.24	4.37	4.40	4.67	4.49	D	-0.257	diamag
10	C_6H_5	$4\text{-}XCI\text{-}C_6H_4$	CH_3	253-254	251-253	64.04	64.20	4.37	4.26	4.67	4.64	E	ca. 0	diamag
11	C_6H_5	$4\text{-}CIC_6H_4$	CH_3	257-258		69.65	69.90	4.17	4.10	3.87	3.80	E	0.976	1.29

[a] Hseu et al. 1963.

[b] Yamada et al. 1966.

[c] Method of syntheses: D, Direct combination; E, Ligand exchange.

TABLE 2. Properties of pyridine adducts [RCOCHC(NR')R"]$_2$Ni•2Py

R	R'	R"	Color	Melting Point°C	Analyses C Calc	Analyses C Found	Analyses H Calc	Analyses H Found	Analyses N Calc	Analyses N Found	Magnetic Susceptibility 10^6xg	Magnetic Susceptibility μeff, (BM)
CH_3	$4\text{-}O_2N\text{-}C_6H_4$	CH_3	Brown	136-136	58.62	58.62	4.92	4.84	12.82	12.84	6.69	3.22
C_6H_5	C_6H_5	CH_3	Pale Yellow	203-206	73.16	72.89	5.55	5.50	8.13	8.26	6.02	3.18
C_6H_5	$4\text{-}ClC_6H_4$	CH_3	Pale Yellow	255.256	66.52	66.30	4.78	4.55	7.39	7.41	5.04	3.00

(1984) detected the intramolecular linkage isomerism of pseudo-tetrahedral nickel(II) bis(chelates), somewhat related to these compounds. The present paper investigates their geometry by analyses of their magnetic properties.

MATERIALS AND METHODS—Previously prepared nickel chelates were recrystallized until their melting points were in agreement with reported values; analyses were performed (Table 1).

New compounds—These were prepared as follows: 4-(4'-nitro-phenyl)iminopentane-2-one was prepared by condensation of 4-nitroaniline (13.8 g, 0.1 mole) and 2,4-pentanedione (11 g, 0.11 mole) in benzene (150 mL) with a drop of conc. H_2SO_4, and using a Dean-Stark tube. After refluxing overnight, the theoretical amount of water had been eliminated. Orange crystals were obtained by cooling and collected by filtration (20.5 g, 93%). Analytically pure material was obtained by recrystallization from benzene-petroleum ether (Martin, Janusonis, and Martin, 1961). The nickel derivative (compound 2) was prepared by dissolving the ligand (1.76 g, 8 mmole) in 40 mL of anhydrous methanol, with bis(4-iminopentane-2-ono) nickel(II), compound 1, (0.51 g, 2 mmole) and refluxing the mixture for 3 hours. Upon cooling, green crystals were collected by filtration, and washed with methanol and acetone. (The yield was 0.47 g, 47%). Recrystallization from toluene afforded green crystals. Micro analyses were performed by Desert Analytics, Tucson, AZ.

Synthesis of bis(3-(4-chlorophenyl)imino)-1,3-diphenylprop-1-ono)-nickel(II)—The ligand was synthesized by refluxing equimolar amounts (0.025 mole) of dibenzoylmethane and 4-chloroaniline in 40 mL of toluene with 2 drops of conc. H_2SO_4 for 12 hours. The mixture was evaporated to 20 mL, then cooled at -17°C. Crystals of unreacted starting materials separated upon cooling and were removed by filtration; the yellow filtrate was evaporated to yield a yellow solid. Column chromatography on silica gel (grade 950, 60-200 mesh) eluted with hexane, and then toluene, separated the yellow product from unreacted starting materials. The product was purified further by recrystallization from 95% ethanol, yellow needles (5% yield), m.p. 144.5-146°C. UV spectrum in methanol: l (log e)=257.6 nm (4.22) and 377.2 nm (4.40). The ligand had been synthesized previously by a different method (Fouli and Beshay, 1980). The ligand (0.13 g, 0.4 mmole) and compound 1 (0.05 g, 0.2 mmole) were dissolved in 15 mL of methanol and refluxed. Yellow-green crystals formed, and after two hours the solution was cooled. The precipitate was collected and washed with ethanol (compound ll, 0.09 g, 61%).

The effect of heating nickel(II)-chelate compounds in methanol-chloroform was studied for three compounds (2, 3, and 5, Table 1). The pure compound (0.14 mmole) was dissolved in a mixture of 22 mL of 11% (v/v) methanol-chloroform and refluxed for 2 hours. Reaction was indicated by a color change, and upon cooling the solution was extracted with water, and the water was tested with $AgNO_3$ solution. These three compounds produced white precipitates. The control sample (solvent mixture only) yielded a trace of silver chloride.

Three compounds of the type $[RCOCHC(NR')R'']_2Ni$ (0.25 g) were dissolved in 10-15 mL of pyridine and refluxed for 2-3 hours. Hexane was added to the cooled solutions until they became turbid. Upon cooling in the freezer, (-17°C), the pyridine adducts were isolated from pyridine-hexane solutions by filtration, and washed with hexane (ca. 0.24 g, 70-76% yield). The melting points, analytical data, and magnetic properties are listed (Table 2).

Magnetic susceptibilities—These were evaluated using a JME magnetic susceptibility balance (Johnson Mathey, Inc., Fabricated Equipment, West Chester, PA). The JME balance measures the equal and opposite force that the sample exerts on a suspended magnet. For each sample, the gram magnetic susceptibility, Xg, was calculated and for those substances that were paramagnetic, the experimental magnetic moment, m_{eff}, was also calculated. The unit was calibrated using $HgCo(SCN)_4$; $Xg = 16.4 \times 10^{-6}$ cgs (Bünzli, 1979), t=22° C.

Molecular weights—Molecular weight for $[C_6H_5COCHC(NC_6H_5)\text{-}C_6H_5]_2Ni$, compound 5, was determined by the Rast method in camphor (Shriner and Fuson, 1948). Weight of sample, 65.4 mg; weight of camphor, 424.4 mg; melting point depression, 8.9°C. Obs.: 687; Calc.: 655. Molecular weight determination of bis(4-iminopentene-2-ono)nickel(II), compound 1, in benzene solution was made by Galbraith Laboratories, Inc. (Knoxville, TN) using a Knauer vapor phase osmometer. Obs.: 265; calc.: 255 (for a monomer).

Spectra—Visible spectra were obtained using a Cary 14 spectro-photometer and a IBM 9420 uv/visible spectrophotometer.

RESULTS AND DISCUSSION—Magnetic properties have been used as a guide to evaluate structure (Cotton and Wilkinson, 1972). Thus for nickel(II) compounds, a so-called d^8 case, paramagnetism should indicate a tetrahedral geometry, and diamagnetism would indicate a planar (or an octahedral) geometry. Bis(4-iminopentane-2-ono)nickel(II) (compound 1) existed as a monomer in benzene, in contrast with bis(2,4-pentanediono)nickel(II), which exists as a trimer (Cotton and Fackler, 1961; Bullen et al., 1965) and presumably with octahedral nickel(II) ions in benzene solution (Cotton and Fackler, 1961). Thus, $[(CH_3COCHC(NH)CH_3)]_2Ni$ does not have an octahedral structure, and since it was resolved partially in benzene (Hseu et al., 1963), it presumably has a distorted planar structure.

Deviation from planarity for compounds of the type $[RCOCHC(NR')R'']_2Ni$ is apparently caused by bulky terminal groups R and R'', with at least one example of distortion (compound 6) caused by a sterically hindered R' group, 2,6-$(CH_3)_2C_6H_3$. With bis(salicylaldiminato)nickel(II) compounds, a planar-tetrahedral equilibrium is also involved, and bulky substituents favored the tetrahedral form (Holm and O'Connor, 1971). Compounds listed in Table 1 with bulky (phenyl) terminal groups were paramagnetic. The molecular weight data of compound 1 are consistent with a monomeric structure.

Geometric isomerism was observed in compound 3/4 and 7/8. Compound 3 (Table 1), prepared by ligand exchange, was resolved (Hseu et al., 1963). Resynthesis of the compound indicated that it was paramagnetic; other workers (Yamada et al., 1966), however, prepared the compound by direct combination, and found that the product was diamagnetic, though its susceptibility value was not recorded. We also prepared the compound by direct synthesis and observed a diamagnetic product (compound 4). Both isomers (3/4) are green, and their existence suggests that the presumed distorted planar-tetrahedral equilibrium is a sensitive one. A second example of planar-tetrahedral isomerism is represented by compounds 7 and 8.

It is possible to relate the magnetic properties to the "stability" of the planar-tetrahedral equilibrium. The rate of racemization of the resolved compounds $[RCOCHC(NR')R'']_2Ni$ as reported by Hseu and co-workers (1963) is a curvi-linear function of the magnetic susceptibility, i.e., $y=0.896 \cdot 10^{-0.105x}$. Here y is the specific rate constant for racemization (as hr^{-1}) and x is the magnetic susceptibility (as 10^6X_g) for compounds 1, 3, 5.

The correlation coefficient (r=0.98) suggests that the rate of racemization and magnetic susceptibility have a common relationship, e.g., the effect of steric factors. The greater the steric distortion, the greater the tendency to attain a tetrahedral structure, and the slower the rate of racemization, which after all, may be regarded as a measure of the tendency of the optically active tetrahedral form to transform from the D to the L form via a planar intermediate. For example, compound 5 has the greatest steric hindrance (six phenyl groups per molecule), the least tendency toward planarity, and the greatest magnetic susceptibility.

Available results do not indicate any notable differences in N-phenyl substitution ($R'=ZC_6H_n$, where Z is 4-nitro, 4-chloro-, or 2,6-dimethyl-); all compounds were diamagnetic ($R=R''=CH_3$). A steric effect was observed previously with the 2,6-dimethylphenyl derivative; a benzene solution of the nickel complex (compound 6) was resolved, and the rate of racemization was less than the unsubstituted compound (Hseu et al., 1963), consistent with the effect of steric strain limiting racemization via a planar structure.

An electronic effect of *N*-phenyl substitution was evident for the 4-chlorophenyl derivative ($R=R''=C_6H_5$). The *N*-4-chlorophenyl compound was less paramagnetic than the N-phenyl compound (1.29 vs 3.73 BM). Similar results were observed for a second series ($R=C_6H_5$, $R''=CH_3$) (ca 0 and 2.45 BM for the 4-chlorophenyl and the phenyl derivatives, respectively). A third series ($R=R''=CH_3$) could not be compared; both derivatives were diamagnetic.

The spectra of the paramagnetic compounds in chloroform solution had three bands (*ca.* 395, 633, 1,150 nm; e ca. 30, $u_3/u_1=1.8$), consistent with an octahedral structure in chloroform. Presumably chloroform is a coordinated solvent. Similar spectra were obtained in pyridine, a stronger coordinating agent than chloroform. The pyridine adducts isolated (Table 2) were paramagnetic, and presumably octahedral complexes.

Coordinated chloroform should be more reactive than uncoordinated chloroform. Prolonged refluxing of 1:10 methanol-chloroform (v/v) solutions of compounds 2, 3, 5 (Table 1) resulted in some dehalogenation and production of chloride ion in greater quantities than with controls. In view of past observations (Martin, 1975; Nahar and Mukhedkar, 1981; Hewes and Martin, 1984; Luschinski and Martin, 1990), this result may be more significant than the isolation of chloroform adducts. Compounds listed in Table 1, thus, may serve as useful models for trihalomethane dehalogenation agents.

Thus, our initial query about the possibility that compounds of the type $[RCOCHC(NR')R'']_2Ni$ would coordinate chloroform has been answered, and we have also provided evidence for facile conversion of some of the compounds from a planar to pseudo-tetrahedral form, as well as to an octahedral compound, depending chiefly upon the terminal substitution as well as the solvent.

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REFERENCES CITED

Angelici, R. J. 1969. Synthesis and Technique in Inorganic Chemistry. Sanders, Philadelphia.

Bünzli, J. C. G. 1979. Comment on the use of $HgCo(NCS)_4$ as a susceptibility standard. Inorg. Chim. Acta 36:L413-L414.

Bullen, G. J., R. Mason, and P. Pauling. 1965. The crystal and molecular structure of bis(acetylacetonato)nickel(II). Inorg. Chem. 4:456-462.

COTTON, F. A. AND G. WILKINSON. 1972. Advanced Inorganic Chemistry, ed. 3, Interscience, New York, p. 897.

————, AND J. P. FACKLER, JR. 1961. Molecular association and electronic structures of some nickel(II) chelates. I. Complexes of pentane-2,4-dione and some 1,5-disubstituted derivatives. J. Am. Chem. Soc. 83:2818-2825.

FOULI, F. A. AND A. D. BESHAY. 1980. Reactions of primary and secondary aromatic amines with aroylphenylacetylenes and configurational assignments of the adducts. Indian J. Chem. 19B:410-412.

HEWES, K. A. AND D. F. MARTIN. 1984. Dehalogenation of three chlorinated hydrocarbons: amine-assisted verus metal-chelate assisted. J. Environ. Sci. Health A19:713-724.

HOLM, R. H. AND M. J. O'CONNOR. 1971. The stereochemistry of bis-chelate metal(II) complexes. Prog. Inorg. Chem. 14:241-401.

HSEU, T. -M., D. F. MARTIN, AND T. MOELLER. 1963. Partial resolution of some copper(II) and nickel(II) ß-ketomine compounds by means of a chromatographic technique. Inorg. Chem. 2:587-590.

KNORR, R. AND F. RUF. 1984. Detection of intramolecular linkage isomerism of a (pseudo)tetrahedral nickel(II) bis(chelate). Angew. Chem. Int. Ed. 23:368-369.

LUSCHINSKI, P. J. AND D. F. MARTIN. 1990. Unpublished results.

MARTIN, D. F. 1975. Kinetics of dehalogenation of chloroform by a metal-chelate system. J. Inorg. Nucl. Chem. 37:1941-1944.

————, G. A. JANUSONIS, AND B. B. MARTIN. 1961. Stabilities of bivalent-metal complexes of some ß-ketoimines. J. Am. Chem. Soc. 83:73-75.

NAHAR, C. T. AND A. J. MUKHEDKAR. 1981. The effect of metal ion in Bis(N-n-butyl, salim) metal(II) on the dehalogenation of chloroform. J. Indian Chem. Soc. 58:343-346.

OLSZEWSKI, E. J. AND D. F. MARTIN. 1965 Interaction of amines and some nickel(II) Schiff-base compounds. I. Amine exchange. J. Inorg. Nucl. Chem. 27:345-351.

SHRINER, R. L. AND R. C. FUSON. 1948. The Systematic identification of organic compounds, ed. 3, John Wiley & Sons, Inc., New York.

YAMADA, S., H. NISHIKAWA, AND E. YOSHIDA. 1966. Nickel(II) and copper(II) complexes of ß-ketoamines derived from ß-diketones and aromatic amines. Bull. Chem. Soc. Japan 39:994-1002.

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CASSYTHA FILIFORMIS AND LIMITS TO GROWTH AND REPRODUCTION OF *SCHINUS TEREBINTHIFOLIUS* IN SOUTHERN FLORIDA

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ABSTRACT: *Brazilian pepper* (Schinus terebinthifolius) *has become an aggressive exotic angiosperm competitor in native southern Floridian habitats over the past few decades. Few environmental limitations to growth and reproduction of this problem exotic seem to exist. However, a native parasitic angiosperm,* Cassytha filiformis, *has been noted parasitizing* Schinus terebinthifolius; *field observation indicates that this parasite may not necessarily limit Schinus' vegetative growth in height, but may significantly limit its foliage production and reproductive capacity.*

THE proliferation of Brazilian pepper *(Schinus terebinthifolius* Raddi [Anacardiaceae]) as an agressive exotic in southern Florida has been well documented in the past several decades (Austin, 1978; Ewel et al., 1982; Doren and Whiteaker, 1990a,b). Property owners and managers currently commit thousands of hours of labor, at great expense, to keep areas free of this exotic that threatens the diversity and stability of native southern Floridian ecosystems. Recently, a native angiosperm parasite, *Cassytha filiformis* L. (Lauraceae) has been noted parasitizing Brazilian pepper in several locations in southern Florida. This suggested the possibility that *Cassytha filiformis* might provide a naturally occurring biological control to the growth and reproduction of Brazilian pepper. The present study is a preliminary investigation of the effects of parasitism by *Cassytha filiformis* on growth and reproductive activity of Brazilian pepper.

Schinus terebinthifolius (Brazilian pepper, Florida holly, pepper tree, pepper bush, pepper hedge; hereafter "Schinus") is a shrub or small tree native to South America. Its growth in our area can be rapid, sprawling, and competitive; it forms nearly monocultural stands in many habitats in southern Florida, but is most aggressive in disturbed areas. Schinus was apparently introduced to our area from Brazil, around the turn of the century, and was noted as a naturalized part of the subtropical Floridian flora by the 1950s (Workman, 1978). Schinus is now common along roadsides and other disturbed mesic habitats in southern Florida, and can be found inhabiting most terrestrial habitats in the southern part of the state.

Schinus' extension growth and leaf production occurs nearly year-round, with some seasonal variation. Ewel (1978) noted a decline in leaf flushing during peak reproductive activity in Schinus plants in southwestern Dade County. Flowering occurs mostly in middle to late autumn; seed production is heaviest in late fall and early winter, but reproductive activity may occur throughout the year.

Cassytha filiformis (love vine, woe vine, laurel dodder; hereafter "Cassytha") was described by Tomlinson (1980) as a "parasitic wiry climber without foliage leaves." Kuijt (1969) indicated the distribution of this species as pantropical and generally limited to coastal habitats. Pinelands, hammocks, and coastal ridge scrub systems are biotopes in which Cassytha is perhaps most common in our area.

Cassytha germinates in soil and establishes itself as a parasite by attaching to grasses or forbs; it subsequently extends to larger vascular plant hosts, finally reaching full development on arborescents (Kuijt, 1969). Oak trees (*Quercus* spp.) are common final hosts for Cassytha in our area. Host infestation (*sensu* Freeland, 1986) occurs by adventitious production of haustoria (roots) from the parasite's stem, and penetration by these structures into host vascular tissues. After penetration, the haustoria integrate parasite xylem cells with the host's xylem, and extract water and mineral nutrients. A similar association with phloem tissues may also occur (Press et al., 1990), but this was not noted in the specimens examined here. Cassytha appears to be a "xylem parasite" (Kuijt, 1969), gathering little more from its hosts than water and dissolved mineral nutrients. In this respect, Cassytha may be considered as a "hemiparasite" that is entirely dependent on its host plants for survival (Watkinson and Gibson, 1987).

Parasitism, or a close relationship (parasitism unconfirmed), has been noted with individuals of many families of vascular plants in southern Florida. Xylem parasites seem somewhat anomalous among parasites, as relatively unspecialized in host selection. As a parasitic plant that is unspecific in its host requirements, Cassytha's habits do not necessarily carry the disadvantage of dying with its hosts, a fate common to other macroparasites (Toft, 1986). Cassytha (in this study) is not typically associated with dead hosts; however, it seems that it may suffer no significant consequence in killing a host, as it may be simultaneously established on adjacent hosts.

Possible Host-Parasite Relationships in These Species—In 1985, I saw Schinus trees along Interstate 95, in Palm Beach County, Florida, that were covered with, and apparently parasitized by, Cassytha. The area of infestation was heaviest north of the City of Boca Raton, in the coastal scrub ridge area, along 2-3 miles of I-95. Areas of lighter infestations extended to the north and to the south. The areas of infestation appear to have increased in this region since then.

Microscopic analysis of cross sections of the Cassytha-infested Schinus stems confirmed xylem parasitism by Cassytha. Growth, leaf production, reproductive activity, and general health of heavily infested Schinus appeared to be reduced.

Also in 1985, I observed scattered Schinus with Cassytha infestation in southwestern Florida (Lee and Collier Counties). Further observations during the summer of 1987 suggested that Cassytha infestation in Schinus on the southern Gulf coast of Florida may have increased over that noted two years previous. In October, 1989, an investigation of Cassytha infestation on Schinus trees was initiated to compare growth and reproduction in non-parasitized and Cassytha-infested individuals in southern Florida.

Methods and Materials—*Measurements of Schinus Trees and Cassytha*—Data were gathered from both non-infested and Cassytha-infested Schinus plants in Collier County, Florida, and in Palm Beach County, Florida. Plants were selected from those found along roadsides when searching for Cassytha. Both infested and non-infested Schinus plants were studied in the same vicinity (usually within 10 meters).

Each tree was measured at a compass reading determined by random number (0-359) selected from a random number table (Rohlf and Sokal, 1981). The center of the origin (trunk) of each Schinus tree was considered as the center of a circle circumscribing the tree; the randomly selected number was considered as a degree reading from a hand held compass oriented to 0 degrees (magnetic North). Canopy contour height was measured at this degree reading point with a flexible metal tape, measuring from the tree apex (point directly above the tree origin, level with the part of the tree highest above the ground) to the ground. The tape was allowed to fall along the outer contours of the tree, to measure total canopy contour. A measure of Cassytha infestation on each Schinus individual was obtained by totaling the amounts of Cassytha stem areas crossing within 1.0 dm beneath the measuring tape while it was held in place for total canopy height measurement.

Quadrat area measurements—A random number between 5 (the number of decimeters on each side of the sample quadrat) and the total tree canopy height was selected as the number of decimeters measured from the tree apex, at which the sample quadrat was located. A 0.25 sq m (5.0 dm X 5.0 dm) quadrat was then placed at that decimeter level against the canopy.

Each side of the sample quadrat was divided into 1.0 dm intervals, to create a grid of 25 1.0 dm squares. These squares were used to determine the amounts of Schinus leaf area and Cassytha in the samples. Within the quadrat, squares that were one-half or more filled with Schinus leaves were counted for a measure (0-25 dm^2) of leaf area. Similarly, squares that were one-half or more filled with Cassytha stems were counted for a measure (0-25 dm^2) of Cassytha within the quadrat. Schinus leaves and/or Cassytha stems within the sample, but not present in sufficient quantity to fill half of any one square were counted as one square.

Total reproductive activity of individual Schinus trees was determined by counting reproductive structures within each quadrat; reproductive structures occuring within 1.0 dm perpendicular to both sides of the quadrat grid were considered to be within the quadrat. In one data set, counts were made for both male and female plants, so that reproductive shoots, flowers, and fruits were counted. Inflorescences are thyrses (i. e., indeterminate reproductive shoots), often with unknown numbers of undeveloped flowers, and with flowers and fruits in various degrees of development; therefore, size ranges were arbitrarily selected to distinguish immature buds, flowers, and fruits. Male and female flower buds 1.5 mm or greater in diameter were counted as flowers. Fertilized female flowers with pistils less than 2.0 mm in diameter were counted as flowers, and fertilized female flowers with pistils greater than 2.0 mm in diameter were counted as fruits.

A second data set was collected five weeks after the first. To measure seed production, only female individuals were considered, and only reproductive axes and developed fruits were counted. Almost no flowers or undeveloped fruits were encountered within the quadrats. Total numbers of reproductive shoots within quadrats were determined in all cases.

Statistical comparisons of reproductive activity, tree height, leaf production, and Cassytha infestation in Schinus were made using Systat 4.1 (Wilkison, 1988). Data were log n + 1 transformed. Goodness of fit was determined by either the F-test for goodness of fit (Sokal and Rohlf, 1981), or Bartlett's test for homogeneity of variances (Wilkison, 1988). Analysis of variance (ANOVA) was used to determine whether there were significant differences both between and within populations. Two-way ANOVAs were used to compare reproductive activity, leaf area, and height of infested and noninfested male and female Schinus plants. One-way ANOVAs were used to compare Cassytha infestation on each gender of Schinus plant, and height, leaf area, and reproductive activity in infested and noninfested female Schinus plants. Total reproductive activity of female plants was analyzed by comparing numbers of fruits, reproductive shoots, and numbers of fruits per reproductive shoot. Reproductive structures per leaf area were analyzed to compare reproductive activity of Schinus found within each quadrat sample.

RESULTS AND DISCUSSION—Schinus produces flowers and fruits year-round (Tomlinson, 1980), but in southern Florida its most active reproductive period is during the late fall and early winter. Flowers and drupes are produced in axillary thyrses. Plants are almost always dioecious, with male and female plants equally divided in the areas sampled; Ewel and co-workers (1982) noted limited amounts (ca. 1%) of sequential dioecy in Dade County populations. Male flowers outnumbered female flowers about 1.4:1 per plant area sampled.

Male and Female Schinus Plants, Infested and Non-infested—Two-way ANOVAs comparing reproductive activity (measured as numbers of reproductive shoots in sample quadrats) and vegetative growth (measured as total plant height) and leaf areas in sample quadrats, showed no significant differences in these growth aspects, between male and female populations. One-way ANOVAs of both plant genders showed no significant differences in reproductive shoot production, leaf production, Cassytha infestation, or total plant height. However, one-way ANOVAs of infested plants and non-infested plants showed significant differences in reproductive shoot production and leaf production, but no significant difference in total plant height (Table 1).

Male Schinus Plants—One-way ANOVAs comparing Cassytha-infested plants and non-infested plants show no significant differences in reproductive shoot production, flower production, or numbers of flowers per reproductive shoot (Table 1).

TABLE 1. Comparisons of growth and reproductive activities of non-infested and parasite infested Schinus trees. Plant heights are measured in decimeters (dm); leaf areas are numbers of square decimeters (dm^2) of leaf area within a 0.25 square meter quadrat sample area; numbers of reproductive structures are from within a 0.25 square meter quadrat sample area. Data were log n + 1 transformed for ANOVA.

Growth Aspect	Non-infested mean(±s.d.)	Infested mean(±s.d.)	F[a]
Plant height (n=147)	29.9(±9.2)	27.3(±9.4)	3.387 n.s.
Leaf area (n=147)	8.5(±4.9)	4.0(±3.4)	21.020 ***
Numbers of reproductive shoots (n=147)	21.4(±16.4)	9.1(±9.6)	30.982 ***
Numbers of male flowers (n=33)	1055.0(±1184.1)	435.2(±717.4)	3.367 n.s.
Numbers of female flowers (n=34)	841.3(±877.0)	169.9(±276.2)	12.311 ***
Numbers of male flowers per shoot (n=33)	47.1(±61.4)	21.5(±22.6)	2.266 n.s.
Numbers of female flowers per shoot (n=34)	42.2(±37.0)	11.5(±12.2)	9.002 **
Numbers of fruits (n=79)	1119.8(±901.4)	321.9(±445.3)	21.102 ***
Numbers of fruits per shoot (n=79)	49.8(±28.9)	25.9(±23.1)	16.206 ***
Numbers of shoots per dm^2 leaf area (n=79)	3.1(±2.1)	2.5(±2.6)	3.803 n.s.
Numbers of fruits per dm^2 leaf area (n=79)	159.2(±112.8)	78.3(±124.1)	13.282 ***

[a]n.s.= no significant difference
*= 0.01<P≤0.05
**= 0.001<P≤0.01
***= P≤0.001 (Sokal and Rohlf, 1981)

Female Schinus Plants—One-way ANOVAs comparing flower production in Cassytha-infested female plants and non-infested female plants show significant differences in reproductive shoot production, numbers of flowers, and numbers of flowers per reproductive shoot (Table 1). One-way ANOVAs comparing Cassytha infested fruit bearing plants and non-infested fruit bearing plants show significant differences in reproductive shoot production, fruit production, number of fruits per reproductive shoot, number of fruits per measured leaf area, and leaf production; no significant difference was found in total plant heights (Table 1).

Adaptations by Schinus—Few limits to growth and reproduction of Schinus populations appear to exist in southern Florida. Ewel (1978) suggested that Schinus may be the "perfect weed" in southern Floridian habitats, considering the area's compatibility with Schinus' life history and phenology. Woodall (1978) stated that no method, other than very labor intensive techniques, was known for controlling this species. Systemic herbicides are more cost and labor effective (Doren and Whiteaker, 1990a,b; Marron, 1990), but these chemicals may carry some potential for soil or ground water contamination, or may be fatal to adjacent plants if not applied properly. Herbivory is not commonly encountered on Schinus, although Cassani et al. (1989) have reported limited predation on Schinus by some lepidopteran larvae.

Freeland (1986) emphasized a loss of fitness of parasitized host organisms, including lowered host reproductive ability. Field observations suggest that infestation of Schinus by *Cassytha filiformis* may limit foliage growth and reproductive activity of this invasive exotic plant. Differences observed in physical appearances of non-infested and Cassytha-infested Schinus plants are distinct. Heavily infested Schinus trees are often nearly defoliated, and may show little or no reproductive activity. At least two dead Schinus trees were noted during field study that had been heavily infested with Cassytha; whether this infestation caused or contributed to the death of these trees is unknown. Significant differences in growth and reproductive activity were determined through analysis of variance (ANOVA), between Schinus populations that were not infested with Cassytha and those that were. These analyses suggest that Cassytha infestation on Schinus adversely affects reproductive activity within the southern Floridian Schinus population. Whether this decrease in seed production will significantly limit Schinus' population is unknown at this time.

CONCLUSIONS—*Vegetative Growth in Schinus and Cassytha Infestation*—Analysis of Variance (ANOVA) comparing heights of Cassytha-infested and non-infested Schinus trees indicated no significant difference between these populations. This lack of significant difference may indicate that either: 1) Cassytha infestation does not significantly affect extension growth in Schinus, 2) Cassytha infestation did not occur in the Schinus tested until after Schinus' extension growth had occurred, or 3) Schinus is able to tolerate or overcome parasitism by Cassytha. However, significant differences in leaf areas, between infested and non-infested Schinus plants, may indicate that Cassytha parasitism significantly reduces Schinus' ability to produce foliage.

Schinus' Reproductive Activity and Cassytha Infestation—Analyses of variance (ANOVAs) comparing growth with gender of infested and non-infested Schinus indicate no significant difference between the two populations, suggesting that any limitations by Cassytha parasitism are not gender specific. Lack of significance in differences of reproductive output between infested and non-infested male Schinus plants suggests that pollen producing Schinus plants may not be significantly affected by Cassytha infestation. Total numbers of seeds (fruits) produced are significantly reduced in the Cassytha-infested population. Also, total numbers of reproductive shoots and numbers of fruits per shoot are significantly reduced, suggesting that infestation by Cassytha inhibits total seed production.

Numbers of reproductive shoots per leaf area within sample quadrats are not significantly different. This suggests that growth of available axillary reproductive buds is not inhibited by Cassytha infestation, and that this particular reproductive activity may not be affected. However, significantly lower numbers of fruits per leaf area within sample quadrats, and significantly lower numbers of fruits per reproductive shoot, indicates that Cassytha infestation may significantly reduce Schinus' reproductive potential by reducing seed production.

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LITERATURE CITED

Austin, D. F. 1978. Exotic Plants and their effects in southeastern Florida. Environ. Cons. 5(1):25-34.

Cassani, J. B., D. R. Maloney, D. H. Habeck, and F. D. Bennett. 1989. New insect records on Brazilian Peppertree, *Schinus terebinthifolius* (Anacardiaceae), in south Florida. Florida Entom. 72(4):714-16.

Doren, R. F. and L. D. Whiteaker. 1990a. Comparison of economic feasibility of chemical control strategies on differing age and ensity classes of *Schinus terebinthifolius.* Nat. Areas J. 10(1):28-34.

——— , and L. D. Whiteaker. 1990b. Effects of fire on different size individuals of *Schinus terebinthifolius.* Nat. Areas J. 10(3):107-113.

Ewel, J. 1978. Ecology of Schinus. Pp. 7-22. *In:* Workman, R. W. (ed.). Schinus. Technical Proceedings of Techniques for control of Schinus in South Florida: A workshop for natural area managers. 1978. The Sanibel-Captiva Conserv. Found. Inc., Sanibel, FL.

——— , D. S. Ojima, D. A. Karl, W. F. Debusk. 1982. Schinus in Successional Ecosystems of Everglades National Park. South Florida Res. Center Rep. T-676. 141 pp.

Freeland, B. 1986. Arms races and covenants: the evolution of parasite communities. Pp. 289-308. In: Kikkawa, J. and D. J. Anderson (eds.). Community Ecology: Pattern and Process. Blackwell Scient. Publ., Oxford.

Kuijt, J. 1969. The Biology of Parasitic Flowering Plants. Univ. Calif. Press. Berkeley.

Marron, J. V. 1990. Pers. commun. Collier County Water Management Department, Naples.

Press, M. C., J. D. Graves, and G. R. Stewart. 1990. Physiology of the interaction of angiosperm parasites and their higher plant hosts. Plant, Cell, Environ. 13:91-104.

ROHLF, F. J. AND R. R. SOKAL. 1981. Statistical Tables. Freeman and Co., San Francisco.

SOKAL, R. R. AND F. J. ROHLF. 1981. Biometry, Freeman and Co., San Francisco.

TOFT, C. A. 1986. Communities of species with parasitic life-styles. Pp. 445-463. *In:* DIAMOND, J. AND T. J. CASE (eds.). Community Ecology. Harper and Row, New York.

TOMLINSON, P. B. 1980. The Biology of Trees Native to Tropical Florida. Harvard Univ. Print. Off., Cambridge, MA. 480 pp.

WATKINSON, A. R. AND C. C. GIBSON. 1987. Plant parasitism: the population dynamics of parasitic plants and their effects upon plant community structure. Pp. 393-411. *In:* DAVY, A. J., M. J. HUTCHINGS, AND A. R. WATKINSON (eds.). 1988. Plant Population Ecology; 28th Symposium of the British Ecological Society. Blackwell Scient. Publ., Oxford.

WILKISON, L. 1988. SYSTAT: the System for Statistics. SYSTAT Inc., Evanston, IL. 822 pp.

WOODALL, S. 1978. Physiology of Schinus. Pp. 23-42. *In:* WORKMAN, R. W. (ed.). Schinus. Technical Proceedings of Techniques for control of Schinus in South Florida: A workshop for natural area managers, 1978. The Sanibel-Captiva Conserv. Found., Inc., Sanibel, FL.

WORKMAN, R. W. 1978. History of Schinus in Florida. Pp. 3-6. *In:* WORKMAN, R. W. (ed.). Schinus. Technical Proceedings of Techniques for control of Schinus in South Florida: A workshop for natural area managers. 1978. The Sanibel-Captiva Conserv. Found., Inc., Sanibel, FL.

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FIRST RECORD OF *CORBICULA* CLAMS WITHIN FLOODED CAVE SYSTEMS—*W. J. Streever*, Department of Zoology, 420 Bartram Hall, University of Florida, Gainesville, FL 32611.

ABSTRACT: *The Asiatic clam,* Corbicula fluminea, *was observed in 4 fully-flooded cave systems along the Suwannee River drainage, with densities of 2820 individuals per m² measured in one of the caves. This is the first record of corbiculid clams occurring within flooded caves.*

THE Asiatic clam, *Corbicula fluminea*, was introduced into North America some time before 1924, and since that time it has invaded major freshwater drainage systems throughout the continental United States (Counts, 1986). An absence of predators, parasites, and pathogens that limit their population growth in Asia, coupled with high rates of development and reproduction, allow American populations of *C. fluminea* to reproduce exponentially and spread rapidly (Counts, 1986). For example, Rodgers and co-workers (1979) reported an upstream colonization rate in the New River, Virginia of 14 km per year, with densities of 1000 individuals per m² after 3 years. Invasion of the Suwannee River drainage was reported in 1967 (Counts, 1986).

A fully-flooded cave system along the Santa Fe River, a tributary to the Suwannee River, was examined on November 25, 1990. The cave system, locally known as Alligator Rise and located 100 m upstream from the U.S. Highway 27 bridge, carries river water which enters through a siphon and exits through a resurgency after traveling approximately 1100 m underground. The cave reaches a depth of greater than 35 m, and has a substrate of coarse sand, clay, limestone, and organic silt. Water current and temperature vary with river conditions.

C. fluminea were found throughout the cave system. At a distance of 100 m from the cave's siphon entrance and at a depth of 30 m, the mean *C. fluminea* density was 2820 individuals per m² (SD=625, n=5). A single density measurement intentionally taken at an area of relatively heavy animal concentration just outside the siphon's opening gave a density of only 391 individuals per m².

Two other fully-flooded cave systems along the Santa Fe River are also known to contain *C. fluminea*. These systems, known locally as Columbia Spring and Myrtle's Crack, are located respectively 200 m downstream from the U.S. Highway 441 bridge and approximately 1 km upstream from the State Highway 47 bridge. Like Alligator Rise, these caves carry river water and appear to support high densities of *C. fluminea*; however, due to logistical difficulties animal densities could not be measured in these caves.

On December 20, 1990, *C. fluminea* were also found within the cave system at Peacock Springs State Recreation Area in Suwannee County. Unlike the cave systems reported above, the Peacock Springs cave system is usually flooded with spring water, not river water, although river water does intrude into the cave system during periods of flood. During periods of normal flow, water from the Floridan aquifer moves through over 7000 m of known underground passages.

C. fluminea were first observed in the Peacock Springs State Recreation Area near the mouth of the cave known as Peacock 3. The floor of Peacock 3 is covered by organic silt with a depth of 1 mm to 100 mm or greater. Sand and limestone underlie the silt. At a distance of 30 m from the entrance to Peacock 3, well within the aphotic zone, the mean *C. fluminea* density was 167 individuals per m^2 (SD=191/m2, n=7). No *C. fluminea* were observed within the cave at distances beyond approximately 70 m from the cave's entrance, and no animals were seen immediately outside the cave's entrance, where large amounts of organic debris lined the bottom. *C. fluminea* populations were less dense or entirely absent from other locations within the Peacock Springs State Recreation Area.

Cave dwelling animals are commonly classified as troglobites, trogloxenes, or troglophiles (Barr, 1968). Troglobites are obligatory cave-dwellers, unable to survive outside of the cave. Trogloxenes, sometimes referred to as accidentals, must leave the cave to acquire food or other resources. Troglophiles are facultative cave-dwellers, capable of maintaining a population within the confines of a cave but also occurring outside of caves. The high densities of *C. fluminea* found in the Santa Fe River caves suggest that they are troglophiles, particularly since animal densities immediately outside of the cave were considerably lower than those found inside the cave. If *C. fluminea* is a troglophile, then the low densities found in the Peacock system, and the absence of animals deep within the cave, must be explained. Three explanations are possible. First, some resource may be missing from the Peacock system that is present within the Santa Fe River caves. Second, substrate with the Peacock 3 cave may not be ideal for *C. fluminea:* Gottfried and Osborne (1982) reported a negative correlation between high levels of organic silt and corbiculid clam density in a Florida stream. Third, the Peacock system may be in the early stages of invasion by *C. fluminea,* in which case densities should increase over the next few years.

C. fluminea utilize bacteria, fish feces, and other seston as food, with filtration rates measured at 500 ml per hour per 25 mm of shell length (Mattice, 1979). The high density of *C. fluminea* found in the Alligator Rise system on the Santa Fe River may be due to food availability within the cave, as the currents flowing through the cave may funnel large quantities of food past *C. fluminea* populations.

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LITERATURE CITED

BARR T.C. 1968. Cave ecology and the evolution of troglobites. Evol. Biol., 2:35-102.

COUNTS, C.L. 1986. The zoogeography and history of the invasion of the United States by *Corbicula fluminea* (Bivalvia: Corbiculidae). Amer. Malac. Bull. Spec. Ed. No. 2:7-39.

GOTTFRIED, P.K., and J.A. OSBORNE. 1982. Distribution, abundance and size of Corbicula manilensis (Philippi) in a spring-fed central Florida stream. Florida Scientist 45:178-188.

MATTICE, J.S. 1979. Interactions of *Corbicula* sp. with power plants. Pp. 119-138. *In:* BRITTON,

J. C., J. S. MATTICE, C.E. MURPHY, and L.W. NEWLAND (eds.). Proceedings of the First International Corbicula Symposium, Texas Christian Univ. Res. Found., Fort Worth, Texas.

RODGERS, J. H., D. S. CHERRY, K.L. DICKSON, and J. CAIRNS. 1979. Invasion, population dynamics and elemental accumulation of *Corbicula fluminea* in the New River at Glen Lyn, Virginia. Pp. 99-110. *In:* Britton, J. C., J. S. Mattice, C.E. Murphy, and L.W. Newland (eds.). Proceedings of the First International *Corbicula* Symposium, Texas Christian Univ. Res. Found., Fort Worth, Texas.

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REVIEW

Crawford H. Greenewalt, *Hummingbirds*, Dover Publications, Inc., 31 East 2nd Street, Mineola, NY 11501. 1990. Pp. vi + 176. Price: $15.95+2.50 (s/h). Paper.

THIS beautifully illustrated book is an unabridged, slightly rearranged republication of the volume first published in 1960 under the auspicies of The American Museum of Natural History, but as young professionals, with a growing family, the original publication was beyond our slender means, much to our regret. The author was a executive with a major chemical firm, who pursued his hobby of studying hummingbirds avidly in his spare time, and his enthusiasm and his ability was legendary. He traveled over 100,000 miles throughout Latin America and the western USA to obtain the information gathered in this book. He also developed new photographic equipment to take the high-speed photographs. Some 67 are provided here, together with 8 additional photographs and 145 detailed line drawings. The volume also includes pioneering information on diverse topics (the subjects' iridescent coloration, complex feather structure, hummingbird characteristics in relation to other birds and flying insects). It is a book for all readers to read and admire. And now young professionals and older ones can afford it.

—Barbara B. Martin and Dean F. Martin, University of South Florida.

Biological Sciences

DIETARY OVERLAP AND ACTIVITY PATTERNS IN SYMPATRIC POPULATIONS OF *SCAPHIOPUS HOLBROOKI* (PELOBATIDAE) AND *BUFO TERRESTRIS* (BUFONIDAE)

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ABSTRACT—*Studies were conducted from April to September, 1988, on the feeding ecology, dietary overlap, diel patterns of activity and temperature relationships of sympatric populations of the eastern spadefoot toad* (Scaphiopus holbrooki) *and the southern toad* (Bufo terrestris) *from Hillsborough Co., FL. A high degree of dietary overlap was found. Insects such as Coleoptera (19-31%) and Formicidae (12-18%), as well as spiders (8-11%), comprised a significant proportion (39-60%) of the diet by volume during spring and summer months. Termites comprised 7-1% of the diet during the spring. No significant overall dietary differences were found between sexes or seasons. Both species were active at body temperatures ranging from 23.5 to 24.4°C.* Bufo terrestris *was not observed at the surface before 2000 hr. The peak period of ground surface activity was 2100-0100 h for* S. holbrooki *and 2200-0300 h for* B. terrestris.

ALTHOUGH general information is available concerning the feeding ecology and dietary preferences of many species of North American anurans (Inger and Marx, 1961; Toft, 1981; Duellman and Trueb, 1986), specific quantitative information is lacking for many pelobatid and bufonid species (Ruibal et al., 1969; Toft, 1985). Bragg (1965) provided some qualitative information on the feeding habits of spadefoot toads which indicated that they feed largely on ground-dwelling arthropods. Pearson (1955, 1957) provided information on temporal patterns of activity, distribution, home range, population dynamics and general feeding trends for *Scaphiopus holbrooki* (Harlan) in central Florida, but did not analyze possible competitive interactions with sympatric populations of *Bufo terrestris* (Bonnaterre). In view of the recent interest concerning competition and resource partitioning in reptiles and amphibians (see review by Toft, 1985), a study was conducted on the dietary preferences, temperature relationships and temporal patterns of activity for the eastern spadefoot toad, *S. holbrooki*, and the southern toad, *B. terrestris*, from Hillsborough Co., Florida. No information is currently available concerning competition and possible dietary overlap between these sympatric species.

METHODS—Animals were collected between April 2 through September 15, 1988. The study area (1.4 km^2) was located near Lettuce Lake Park, Hillsborough Co. (28°06' N, 82°21'W). The physical features and dominant vegetation of this site were previously described by Punzo (1990). A randomized block design (Krebs, 1989) was used to identify ten sample quadrats, each with an area of 10 m^2. Toads were collected at night using a variety of techniques including pitfall traps (Punzo, 1990), on foot with the use of head lamps, and drift fences (Punzo (1974). Drift fences were constructed of 50 cm high aluminum flashing. Within each quadrat, drift fences were placed along five transects with paired pitfall traps (100 liter buckets) on opposite sides of the fence at 2 m intervals. Traps were placed in the ground with the lip of the bucket flush with the

TABLE 1—Stomach content analyses for *Scaphiopus holbrooki* (N=105) and *Bufo terrestris* (N=154). Data represent different individuals (no recaptures). The results are expressed as number of prey (N), frequency (F, percent of toad stomachs containing a particular prey item), and percent volume (V). There were no significant differences in dietary composition between sexes for both species.

	S. holbrooki (N=105)[2]						*B. terrestris* (N=154)[3]					
	Spring[4]			Summer			Spring			Summer		
Prey Taxon[1]	N	F	V	N	F	V	N	F	V	N	F	V
Coleoptera			24.2			30.9			19.3			28.3
Carabidae (A)	73	96.7	8.1	47	88.6	12.4	104	90.8	7.3	47	66.1	11.2
Cicindelidae (A)	10	16.4	0.5	7	15.9	1.1	12	13.8	0.4	14	20.9	0.3
Lampyridae (A)	0	0	0	6	13.6	0.4	0	0	0	9	13.4	0.2
Scarabaeidae (A)	9	14.8	4.3	14	22.9	6.9	7	8.0	3.7	11	16.4	5.8
Tenebrionidae (A)	4	6.6	1.4	7	15.9	1.7	9	10.3	0.5	13	19.4	1.1
Unidentified (A,L)	67	80.3	9.9	52	90.9	8.4	104	91.9	7.4	73	85.1	9.7
Diptera (A)	28	39.3	1.4	31	65.9	1.6	7	8.0	0.8	9	11.9	1.5
Hemiptera			3.3			3.4			0.7			1.7
Coreidae (A, N)	0	0	0	4	9.1	0.4	3	3.4	0.3	0	0	0
Miridae (A, N)	3	4.9	1.1	5	11.4	1.7	0	0	0	6	8.9	1.2
Reduviidae (A, N)	0	0	0	4	9.1	0.6	0	0	0	0	0	0
Unidentified	6	9.8	2.2	2	4.5	0.7	7	8.0	0.4	5	7.5	0.5
Homoptera (A, N)	3	4.9	1.3	0	0	0	0	0	0	0	0	0
Hymenoptera												
Formicidae (A)	128	96.7	17.1	91	79.5	17.6	156	88.5	11.9	147	89.5	18.2
Isoptera (A)	207	98.3	11.3	47	26.2	3.1	96	79.3	6.9	34	32.8	5.4
Lepidoptera (A)	37	34.4	4.1	35	79.5	3.9	67	70.1	4.4	51	65.7	4.1
(L)	11	14.7	1.6	29	50.0	2.1	41	40.2	3.1	63	86.6	2.9
Orthoptera			4.1			4.0			1.8			1.7
Acrididae (A, N)	5	8.1	3.0	7	15.9	3.8	7	8.0	1.8	11	14.9	2.8
Tettigoniidae (A)	0	0	0	3	6.8	0.2	0	0	0	4	5.9	0.3
Unidentified (A, N)	3	4.9	1.1	0	0	0	0	0	0	5	7.5	1.2
Unidentified Insecta	81	93.4	23.2	73	88.6	22.5	119	93.1	35.1	51	71.6	21.5
Arachnida												
Aranea	24	31.1	8.4	31	59.0	10.9	45	42.5	7.9	61	85.111.4	
Annelida	0	0	0	6	13.6	0.5	58	56.3	8.1	43	59.7	10.4

[1] Prey categories: A (adults) , N (nymphs), L (larvae).

[2] Number collected during spring months= 61; summer= 44.

[3] Number collected during spring months =87; summer= 67.

[4] Spring (April 2-June 20); Summer (June 21-Sept. 15 .

ground surface. Time, place of capture , snout-vent length (SVL) and sex were recorded for each animal. Individuals were toe-clipped (Martof, 1953) and released for future demographic studies. Pitfall traps were checked at hourly intervals between 1800 and 0400 hrs. Immediately following capture, toads were removed from traps using insulated gloves and body (cloacal) temperatures were recorded with a Schultheis thermometer as described by Brattstrom (1963). Air temperatures were measured at ground level.

Stomach contents were obtained from anaesthetized toads (mean SVL : 41-70 mm) within 8 hr of capture using the stomach-flushing technique described in detail by Legler and Sullivan (1979). Data from stomach contents were combined for juveniles and adults since preliminary data (Punzo, unpublished data) had indicated no significant dietary differences between these age classes in this area. Since it is known that many insects in Florida show distinct seasonal activity patterns peaking before or shortly after June 20 (Deyrup, 1990), prey items were listed separately for spring and summer months. Toads were held by hand and their mouths were gently opened with a plastic probe. Plastic coupling rings (6-10mm diameter) kept the mouth opened at a maximum gape during the procedure. A Teflon intravenous catheter (Abbott Laboratories, Chicago) was attached to a disposable plastic syringe (1-10 cm^3) equipped with a compression spring mechanism which automatically refills the syringe to 70% capacity after the plunger is depressed. With the mouth opened, the flushing canula was passed through the ring into the esophagus and the stomach where it rested against the pyloric region. Once in place, water from the syringe was gently pumped into the stomach with sufficient force to flush out food material. The emergent food bolus was quickly removed with forceps to prevent any obstruction of the pharyngeal region. The stomach contents for each toad were placed in individual glass vials containing 80% ethanol for later identification and deposited in the University of Tampa Invertebrate Collection. Prey items were identified to Order and Family, depending on the stage of digestion. The information obtained for stomach contents reported in this study represents data from different individuals (no recaptures). The length (a) and width (b) of each prey item were measured to the nearest 0.01 mm (excluding legs and antennae) and the volume was determined according to the formula for the volume (V) of a prolate spheroid (Dunham, 1983): $V=4/3\,(a/2)(b/2)^2$.

Levins' measure of niche breadth (B) was calculated from data based on the size category (% volume) of food items as described by Krebs (1989). Values can range from 0 (prey species in only one resource category) to 1.0 (species represented equally in all resource categories). Dietary and temporal niche overlap (D) were calculated according to the method described by Floyd and Jenssen (1983) (Equation 1) :

$$D = 1 - 1/2 \sum_{i=1}^{n} \left| P_{xi} - P_{yi} \right| \qquad (1)$$

where P_{xi} and P_{yi} are frequencies of prey classes or time intervals for species x and y, respectively, for the i^{th} category. The index, D, can range from 0 (no overlap) to 1.0 (complete overlap). Frequencies (%) of occurrence for various prey taxa (trophic niche) and time intervals of ground surface activity (temporal niche) were used for the determination of D (Schoener, 1968 ; Floyd and Jenssen, 1983).

Stomach content analyses and temporal patterns of activity were analyzed utilizing a three-way classification ANOVA. Correlation coefficients (r) were computed between air and body temperatures. All statistical procedures followed the procedures outlined by Sokal and Rohlf (1981).

RESULTS—An ANOVA showed no significant differences in stomach contents as a function of SVL ($p>0.50$) , sex ($p>0.45$) or season ($p>0.37$). The major prey types during the spring and summer months for both species were beetles (Coleoptera, 19-31%), ants (Formicidae, 12-18%), unidentified insects (22-35%), and spiders (8-11%). Termites (Isoptera) comprised a significant portion of the diet during the spring (7-11%) but decreased markedly (3-5%) during summer months ($p<0.01$, Two Sample Means Test, assuming unequal variance, Sokal and Rohlf, 1981), reflecting differences in the seasonal activities and abundance characteristic of termites (Skaife, 1961).

Nocturnal arthropods with well-known chemical defenses that were commonly found in the study area, such as blister beetles (Meloidae), velvet ants (Mutillidae), stink bugs (Pentatomidae) and millipedes, were not found in any of the stomachs. *Scaphiopus holbrooki* and *B. terrestris* have very similar diets as indicated by the high degree of dietary overlap (D=0.81, Eqn. 1). Measurements of trophic niche breadth indicate that most prey species are represented by only a relatively few resource categories (Table 2).

TABLE 2. Levins' measure of trophic niche breadth (B) based on size category (% volume) of food items for *Scaphiopus holbrooki* and *Bufo terrestris* .

Season	*S. holbrooki*	*B. terrestris*
Spring	0.3842	0.3556
Summer	0.3481	0.3845

There were no significant differences in body temperatures between species or sexes ($p>0.02$) (Table 3). Correlations (r) between body and air temperatures were significant. Linear regression of body and air temperaturtes was tested by analysis of covariance (Sokal and Rohlf, 1981). Slopes of the regression lines were significantly different at the 0.01 level of significance (body temperature, $Y=2.127+0.187\ X$; air temperature, $Y=4.462+0.072\ X$). Both species were active at a mean body temperature of 23.5°C and an air temperature of 26.7°C during the spring, and 24.2-24.4 and 28.4°C, respectively, during summer months.

TABLE 3. Air (AT) and body (BT) temperatures for *Scaphiopus holbrooki* and *Bufo terrestris*. All correlations (r) are significant ($p<0.01$). No significant differences were found between sexes.

		Temperature (°C)[1]		
		Body	Air	
Species	N	X ± SE	X ± SE	r
S. holbrooki				
Spring	61	23.5 ± 0.11	26.7 ± 0.33	0.781
Summer	44	24.4 ± 0.09	28.4 ± 0.51	0.802
B. terrestris				
Spring	87	23.5 ± 0.12	26.7 ± 0.33	0.813
Summer	67	24.2 ± 0.13	28.3 ± 0.41	0.785

[1] All temperatures measured at time of capture. Body temperaturess are cloacal temperatures measured with a Schultheis thermometer.

Both species were strongly nocturnal (Table 4). No individuals of either species were observed at the surface before 2000 h. The peak period of surface activity during the spring was between 2100 and 0100 h for *S. holbrooki* and between 2200 and 0300 h for *B. terrestris*. Fewer individuals (3%) of *S. holbrooki* were active between 2100-2159 h during summer months as compared to those active at the same period of time during the spring (7%) when air temperatures are more moderate. *Scaphiopus holbrooki* became active at the surface earlier than *B. terrestris*, and *B. terrestris* remained active from 0200 until 0300 h (9-18%). Activity for *S. holbrooki* declined rapidly between 2400 and 0100 h. Calculation of the temporal niche overlap (D) as described by Floyd and Jenssen (1983) yielded a value of 0.71 for the spring and 0.66 for the summer (see Eqn. 1).

TABLE 4—Percentage of toads active at hourly intervals during spring and summer, 1988 (18=1800 to 1859 hr). N=number of different toads observed during each season. No significant differences were found between sexes.

		Time of activity (10-2 hr)										
Species	N	18	19	20	21	22	23	24	01	02	03	04
Scaphiopus holbrooki												
Spring	61	0	3.1	3.6	6.6	22.8	30.2	20.1	10.1	3.1	0.4	0
Summer	44	0	2.4	2.7	2.8	18.9	30.8	25.9	11.6	2.1	1.7	1.1
Bufo terrestris												
Spring	87	0	0	0	4.0	11.4	21.7	19.4	12.0	16.6	9.7	5.1
Summer	67	0	0	0.8	3.4	5.9	16.9	20.3	19.5	17.8	8.5	6.8

DISCUSSION—The results of this study indicate that beetles, ants, spiders and termites collectively comprise a significant proportion of the total diet of these anurans. It is well known that the use of similar resources by sympatric species indicates a potential for competition (Huey and Pianka, 1977; Toft, 1980, 1981). The high degree of dietary overlap between these species suggests the potential for interspecific competiton, although overlap is not necessarily proportional to the intensity of competition (Duellman and Trueb, 1986). Individuals of *B. terrestris* exhibited a slight shift in their diel activity pattern which may serve to reduce competition. Microhabitat, food and time represent the three major categories of resource dimensions (Pianka, 1986). Microhabitat is frequently the dimension that is partitioned first by most amphibians and reptiles (Toft, 1985) with the exception of snakes (Arnold, 1972). Despite the importance of habitat, most amphibians (Jones, 1982; Toft, 1980, 1985; Duellman and Trueb, 1986) and reptiles (Pianka, 1986) exhibit some degree of food partitioning but there was little evidence of this between the syntopic species in the present study.

It has been suggested (Toft, 1985) that the prey of most anurans can be divided into two main categories, (1) ants and other slow-moving, chitinous arthropods, and (2) all other types. Ants constitute a significant component of the diet in many species of bufonids, dendrobatids, and other anurans (Inger and Marx, 1961; Duellman and Trueb, 1986)). However, ants comprised no more than 12-18% of the total diet in the present study.

Although time of activity appears to be the least important dimension partitioned in amphibians and reptiles (Schoener, 1974; Toft, 1985), it has been shown to occur in some species (Jones, 1982). Some sympatric predators exhibit differences in temporal patterns of activity (Pianka, 1986). Such interspecific nonsynchrony may result in a decrease in the number of encounters between predators thereby reducing interference competition (Huey and Pianka, 1983). It may also reduce dietary overlap resulting in a decrease in exploitation competition. In the present study, a slight degree of diel separation was found between these toads as indicated by the index of overlap. The shift toward earlier hours exhibited by *B. terrestris* may reduce competition in as much as there was no evidence that it offered them any differences in thermal environment or types of prey available. Both species were strongly nocturnal and this is in general agreement with what little information is available on *S. holbrooki* (Pearson, 1955; Bragg, 1965) and *B. terrestris* (Ashton and Ashton, 1988) as well as other pelobatids (McClanahan, 1967; Ruibal et al., 1969) and bufonids (Toft, 1985) from different regions.

The sympatric anurans, *S. holbrooki* and *B. terrestris* exhibit a high degree of dietary overlap regardless of sex and demographic age class. Diel activity patterns show a moderate degree of overlap. Future studies should investigate the possible differences in microhabitat preferences and seasonal activity patterns. In addition, it would be valuable to study dietary preferences and diel activity patterns in allopatric populations .

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LITERATURE CITED

ARNOLD, S. J. 1972. Species densities of predators and their prey. Amer. Nat. 106: 220-236.

ASHTON, R. E. JR. AND P. S. ASHTON. 1988. The amphibians. *In*: Handbook of Reptiles and Amphibians of Florida. Part III., Windward Publs., Inc., Miami, Florida, 191 pp.

BRAGG, A. N. 1965. Gnomes of the night: the spadefoot toads.Univ. Pennsylvania Press, Philadelphia, 137 pp.

BRATTSTROM, B. H. 1963. A preliminary review of the thermal requirements of amphibians. Ecology 44: 238-255.

DEYRUP, M. 1990. Footprints on the sands of time. Fla. Entomol. 34:1-11.

DUELLMAN, W. E. AND L. TRUEB. 1986. Biology of amphibians. McGraw-Hill, New York, 670 pp.

DUNHAM, A. E. 1983. Realized niche overlap, resource abundance, and intensity of interspecific competition. Pp. 261-280. *In*: HUEY, R. B., PIANKA, E. R., AND T. W. SCHOENER (eds.), Lizard Ecology, Harvard Univ. Press, Cambridge.

FLOYD, H. B. AND T. A. JENSSEN. 1983. Food habits of Jamaican lizard *Anolis opalinus:* resource partitioning and seasonal effects examined. Copeia 1983(2):319-331.

HUEY, R. B. AND E. R. PIANKA. 1977. Patterns of niche overlap among broadly sympatric and narrowly sympatric Kalahari lizards (Scincidae : *Mabuya*). Ecology 58:119-128.

———. AND E. R. PIANKA. 1983. Temporal separation of activity and interspecific dietary overlap. Pp. 281-296. In: HUEY, R. B., PIANKA, E. R. AND T. W. SCHOENER (eds.), Lizard Ecology. Harvard Univ. Press, Cambridge.

INGER, R. F. AND H. MARX. 1961. The food of amphibians. Pp. 3-85. *In*: MISSION, C. F. (ed.), Exploration du Parc National de l'Upemba, Imprimerie Hayes, Brussels.

JONES, K. L. 1982. Prey patterns and trophic niche overlap in four species of Caribbean frogs. Pp. 49-55. *In*: SCOTT, N. J. (ed.), Herpetological Communities, U.S. Dept. Interior Wildlife Res. Rep. 13, Washington, D.C.

KREBS, C. J. 1989. Ecological Methodology. Harper and Row, Publ., New York, 654 pp.

LEGLER, J. M. AND L. J. SULLIVAN. 1979. The application of stomach flushing to lizards and anurans. J. Herpetol. 35:107-110.

MARTOF, B. S. 1953. Territoriality in the green frog, *Rana clamitans*. Ecology 34:165-174.

MCCLANAHAN, L. 1967. Adaptations of the spadefoot toad, *Scaphiopus couchi*, to desert environments. Comp. Biochem. Physiol. 20:73-99.

PEARSON, P. G. 1955. Population ecology of the spadefoot toad, *Scaphiopus h. holbrooki* (Harlan). Ecol. Monogr. 25:233-267.

———. 1957. Ecological studies on *Scaphiopus holbrooki* (Harlan). Ecology 38:580-586.

PIANKA, E. R. 1986. Ecology and natural history of desert lizards: analyses of the ecological niche and community structure. Princeton Univ. Press, Princeton, New Jersey, 208 pp.

PUNZO, F. 1974. An analysis of the stomach contents of the gecko, *Coleonyx brevis*. Copeia 1974(3):779-780.

———. 1990. Feeding ecology of the six-lined racerunner *(Cnemidophorus sexlineatus)* in southern Florida. Herp. Rev. 21(2):33-35.

RUIBAL, R., TEVIS, L. AND V. ROIG. 1969. The terrestrial ecology of the spadefoot toad, *Scaphiopus hammondi*. Copeia 1969(3):571-584.

SCHOENER, T. W. 1968. The *Anolis* lizards of Bimini: resource partitioning in a complex fauna. Ecology 49:704-726.

———. 1974. Resource partitioning in ecological communities. Science 185: 27-39.

SKAIFRE, S. H. 1961. Dwellers in darkness. Doubleday Co., New York, 180 pp.

SOKAL, R. R. AND AF. J. ROHLF. 1981. Biometry. 2nd ed. W.H. Freeman and Co.,New York, 859 pp.

TOFT, C. A. 1980. Feeding ecology of thirteen syntopic species of anurans in a seasonal tropical environment. Oecologia 45:131-141.

———. 1981. Feeding ecology of Panamanian litter anurans: patterns in dietand foraging mode. J. Herpetol. 15:139-144.

———. 1985. Resource partitioning in amphibians and reptiles. Copeia 1985(1):1-21.

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THE GENUS *HYPOXIS* (HYPOXIDACEAE) IN FLORIDA

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ABSTRACT: *Five of the seven species of* Hypoxis *reported from the United States and Canada are found in Florida. A key for the identification of flowering specimens is presented. The known distribution of each species is mapped and habitat requirements are discussed. Also, a summary of ecological observations for each species is provided.*

HYPOXIS is a genus of 80 to 100 species, found mostly in the warm temperate regions of the southern hemisphere with a majority of the species being found in southern Africa. A secondary center of diversity is found in the southeastern United States where 6 species occur (an additional species, *H. mexicana*, is restricted to Arizona). Five of the species (*Hypoxis juncea* J. E. Smith, *H. leptocarpa* (Engelmann & Gray) Small, *H. sessilis* L. and *H. wrightii* (Baker) Brackett) are largely restricted to the Atlantic Coastal Plain province of the Southeast and are found in Florida. The sixth southeastern species, *H. hirsuta* (Linnaeus) Coville, is found throughout the eastern United States, but has not been collected in Florida. It has been collected in southern Alabama (Mobile county), and may yet be found in the western parts of the Florida Panhandle.

The first detailed work on *Hypoxis* in the United States was provided in the revision by Brackett (1923). Her work covered all species in this hemisphere, and was the first to stress the use of seed characteristics in identifying species. While the importance of the seed characteristics has been verified over the years, her revision contained very little information on floral characters and has been of limited use when trying to identify the great majority of specimens that lack seeds.

Most subsequent workers have explicitly followed Brackett (1923), adopting her assignment of taxa and copying her key to the species. Only two modifications have been proposed in Brackett's scheme relevant to Florida species. Small (1933b) raised Brackett's *H. hirsuta* var. *leptocarpa* to specific rank. Fernald (1935) proposed *H. longii* as a new species and Taylor and Taylor (1981) suggested it might occur in Florida.

The primary difficulty encountered when working with *Hypoxis* is phenotypic plasticity combined with the similarity in size and general appearance of all North American species. Still, a majority of seedless specimens can easily be identified to species on the basis of simple characters such as leaf width or the relation between ovary length and sepal length. In perhaps 20% of the specimens, a detailed consideration of several morphological characters is required for identification. Fewer than 1% of the seedless specimens I have examined from Florida cannot be confidently associated with a species. Specimens of *H. rigida*, *H. sessilis* and *H. wrightii* have proven the most difficult to separate without seeds.

GENERAL CHARACTERISTICS OF *HYPOXIS*—All species in the genus have a similar organization. They are small herbs with grass-like leaves; shaggy, often irregularly stellate pubescence with long, twisted unicellular arms; and a fleshy, vertically growing stem (often referred to as a corm) whose top is 1 to 4 cm beneath the ground surface. The position of the stem relative to the ground surface is maintained by contractile roots. Typically, old portions of the stem disintegrate at the same rate as new growth occurs, giving the stem a globose appearance, but the older portions of the stem are occasionally persistent in *H. juncea*. This gives rise to an elongated cylindrical stem as noted by Small (1933b). More rarely, less pronounced elongation of the stem will be found in other species, particularly *H. leptocarpa.*

The inflorescences are solitary in the leaf axils and are virtually always shorter than the leaves. They consist of a scape topped by a few-flowered raceme (Fig 1). Scapes continue to grow after anthesis and fruiting scapes may be twice as long as flowering scapes. A single plant may bear up to four inflorescences in various stages of maturity. Each flower pedicel is subtended by a bract. The inflorescence, especially the ovary, is, in most cases, considerably more pubescent than the leaves.

Flowers in our species are uniformly yellow with very similar, but distinguishable, sepals and petals. The abaxial surface of the sepals is pubescent and the adaxial surface is glabrous. Both surfaces of the petals are glabrous. Flowers open about one hour after sunrise and typically close by mid-afternoon (later on overcast days) in all Florida species. The perianth lobes are persistent on the fruit through maturity. The mature fruit is a capsule. There are no apparent adaptations for seed dispersal.

Usually, populations of *Hypoxis* are monospecific although exceptions are found. Mixed populations with *H. sessilis* and *H. wrightii* or *H. juncea* and *H. sessilis* have been found, and *H. juncea* has been found growing within a few meters of *H. rigida.* It is likely that the predominance of monospecific populations has more to do with the limited dispersal ability of the plants than ecological differences between the species.

MATERIALS AND METHODS—This work is based largely on detailed field study of four *Hypoxis* species in Florida: *H. juncea, H. leptocarpa, H. sessilis,* and *H. wrightii.* *H. rigida* has also been studied in the field and in cultivation, but not as intensively. Herbarium specimens from major national and Florida collections provided the distributional data used in constructing the range maps. A list of specimens examined is available from the author.

During the field studies, inflorescences with mature capsules were collected in populations of *H. juncea*, *H. sessilis*, and *H. wrightii*. These inflorescences were air dried and measurements were made of scape length, bract length, pedicel length, capsule length and sepal length. Similar measurements were made on herbarium specimens with suitable open flowers. In addition, corm width and leaf width were measured on the herbarium specimens.

TAXONOMICALLY IMPORTANT CHARACTERS—*Vegetative characters*: A lack

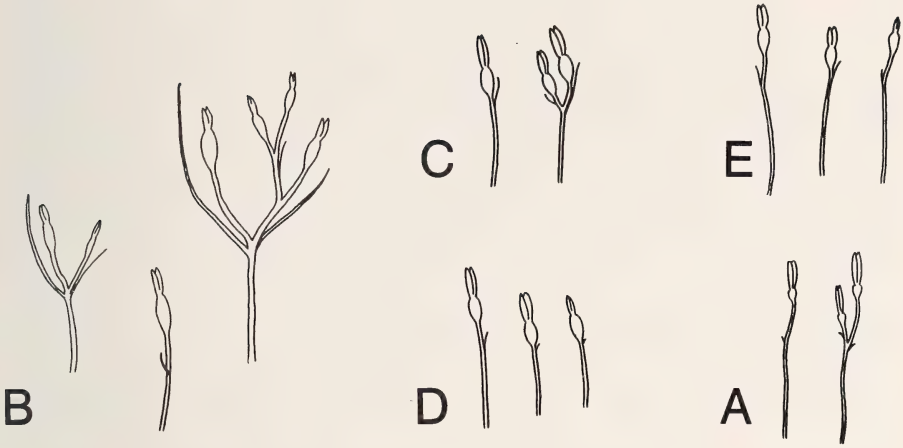

FIG 1. Schematic representation of the variations encountered in the inflorescences of Florida species of *Hypoxis*. A. *H. juncea;* B. *H. leptocarpa;* C. *H. rigida;* D. *H. sessilis;* E. *H. wrightii.*

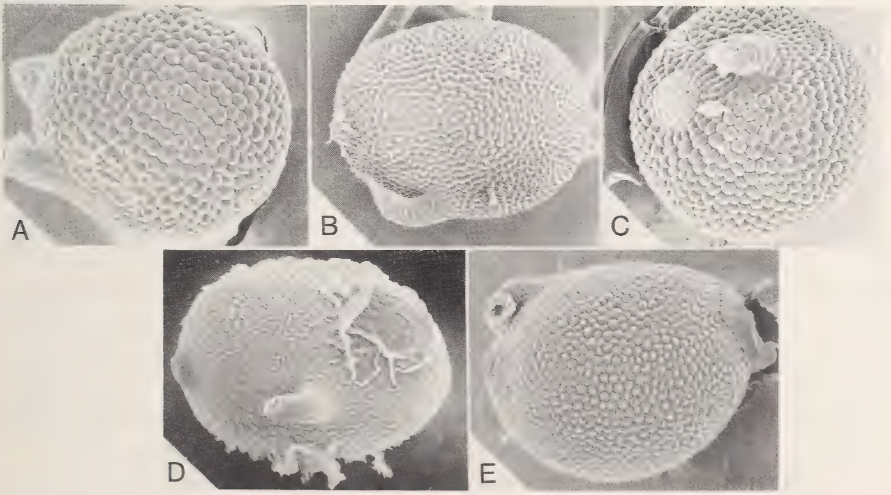

FIG. 2. SEM micrographs of mature seed from the Florida species of Hypoxis showing the characteristic surface sculpturing of each species. A. *H. juncea;* B. *H. leptocarpa;* C. *H. rigida;* D. *H. sessilis;* E. *H. wrightii.*

of leaf pubescence can be used to separate *H. leptocarpa* and *H. juncea* from the remaining species which are conspicuously pubescent (at least at the leaf bases). *H. juncea* occasionally has leaves that are conspicuously pubescent, but it is then separated from other Florida species in having filiform leaves which are roughly as thick as they are wide. In cross section, these leaves are roughly triangular. Other species, especially *H. sessilis* and *H. wrightii*, can have very narrow leaves, but they remain flat in cross section.

Inflorescence and floral characters:—Flower bract and pedicel length, especially relative to each other and flower size are usually the most informative characters on specimens lacking seeds (Fig. 1). The greatly elongated bracts shown in Fig. 1b are diagnostic for *Hypoxis leptocarpa*. Very short, inconspicuous bracts are found only on *H. juncea* (Fig. 1a) and *H. sessilis* (Fig. 1d). Perianth lobes conspicuously longer than the ovary are evident in all specimens of *H. juncea* and many specimens of *H. sessilis.* The anthers of *H. juncea* and *H. rigida* are usually considerably longer than those of the remaining species, but this character cannot reliably be used in isolation.

Seed characters:—The seed characters introduced by Brackett (1923) are extremely useful in the study of American *Hypoxis*. These include the color and sculpture (Fig. 2) of the seed coat surface. The color is dark brown in *H. wrightii,* iridescent brown in *H. sessilis* and black in the remaining Florida species. The iridescent color (apparent only in bright light) of *H. sessilis* is due to a loose membranous covering over the seed (Fig. 2d). In *H. leptocarpa* and *H. wrightii*, the seed surface is covered by pointed projections (Fig. 2b and 2e) while the remaining species have rounded or flattened surface projections. As can be seen, the seed coats of *H. juncea* (Fig. 2a) and *H. rigida* (Fig. 2c) have a similar surface pattern. These two species are easily separated by vegetative characters so this poses no problem. In addition to color and sculpture, the species are generally distinguished by differences in seed size and weight although these differences cannot be considered diagnostic. *H. juncea* and *H. wrightii* have small seeds, the other North American species have large seeds.

SYSTEMATIC TREATMENT—The following key will serve to identify most flowering specimens for which the important characters are accessible to study. When specimens are collected or mounted in such a way that the important characters are not visible, application of the key will be difficult or impossible. If mature seeds are available, comparison with the seed coat characters provided in the species descriptions and shown in Fig. 2 will provide the easiest means of identifying the species.

Perianth measurements refer to chasmogamous flowers in all cases. Specimens with cleistogamous flowers almost invariably have mature seed. Measurements are given for sepals alone, since it is very common to have only sepals accessible on specimens. In any case, measurements for sepals and petals are identical at the degree of accuracy used in the descriptions.

Synonyms relevant to Florida are given in the species descriptions following the key.

Key to Species:

1. Leaves glabrous or with a few trichomes near the base.
    2. Leaves not over 1 mm wide, roughly triangular in cross section, stiff; floral bract usually less than 1 mm long; ovary densely pubescent; seeds with truncated pebbling, black..1. *H. juncea*
    2. Leaves over 2 mm wide, flat in cross section, soft and flexible; floral bract always longer than 1 mm; ovary with scattered trichomes; seeds muricate, black..2. *H. leptocarpa*
1. Leaves pubescent, at least towards the base.
    3. Pedicel more than twice as long as the subtending bracts and longer than the attached flower...1. *H. juncea*
    3. Pedicel less than twice as long as subtending bract and usually shorter than the attached flower.
        4. Anthers greater than 2 mm in length.................................3. *H. rigida*
        4. Anthers less than 2 mm in length.
            5. Sepals 1.5 to 2 times as long as the ovary; seeds pebbled, with an iridescent membranous coat...4. *H. sessilis*
            5. Sepals less than 1.5 times the length of the ovary, usually the two about equal; seeds minutely muricate, dark brown ...5. *H. wrightii*

1. HYPOXIS JUNCEA J. E. Smith, Spicil. Bot. 2: 15, pl. 16. 1792. Type: Smith s.n. s.d. (holotype:BM).

Leaves few to many, usually stiff, with a roughly triangular cross section or a conspicuously thickened midvein, 0.3-1.0 mm wide, 5-40 cm long, glabrous to thinly pubescent. Bases of dead leaves sometimes breaking down into persistent fibers, these fibers commonly found loosely attached to the stem around the living leaves. Inflorescence with 1-2 (3) flowers, lowest two flowers (when present) not paired. Scape (5) 6-16 (19) cm long. Bract 0.1-0.7 (1.2) cm long, much shorter than pedicel. Pedicel (0.5) 1.0-2.6 (2.8) cm long, equalling or slightly shorter than the flower. Sepal 0.6-1.3 (1.5) cm long, 0.2-0.4 cm wide. Anthers (1.3) 1.8-3.3 mm long, usually longer than the filaments. Ovary obconic, (0.2) 0.3-0.5 (0.7) cm long, 0.1-0.2 cm wide at top, shorter than sepals. Capsule obovate, 0.3-0.5 cm long, 0.2-0.3 cm wide. Seed 0.7-1.0 mm long, black, with low, rounded pebbling on the surface.

Most specimens of *H. juncea* are easily recognizable by the very narrow leaves. Identification is verified by the combination of nearly glabrous to very sparsely pubescent leaves with triangular cross-section and sepals much longer than the ovary or capsule. When the leaves are more heavily pubescent and it is not possible to determine the cross-section, specimens can be confused only with extremely narrow-leaved *H. sessilis* or *H. wrightii*. It differs from *H. wrightii* by having a short, usually inconspicuous bract and from *H. sessilis* (which often also has a short bract) by having a pedicel which is much longer than the bract. The elongated stem noted by Small (1933b) is unique to this species in Florida, but is so uncommon that it will rarely be helpful for identification.

This species is far more common in Florida than the surrounding states, even though it was described from South Carolina. It is found throughout the state (Fig. 3a) and is probably missing only from Dade and Monroe counties at the southern tip of Florida. It is most abundant in poorly drained, but not flooded, pinelands (pine flatwoods) but it can also be found on xeric sand ridges.

It flowers abundantly in burned pinelands (Small, 1933a), and, as a consequence, is frequently collected. The peak flowering season is late spring (Apr-May) although plants can be found in bloom at any time of year. It will also bloom abundantly at any time of year in response to fire or comparable disturbance. Within the flatwoods, it is most common around the edges of seasonal ponds. Populations are frequently dense. It is likely that the species is obligately outcrossing. Cultivated plants fail to produce seed unless flowers are deliberately pollinated and I have never observed cleistogamously produced fruit.

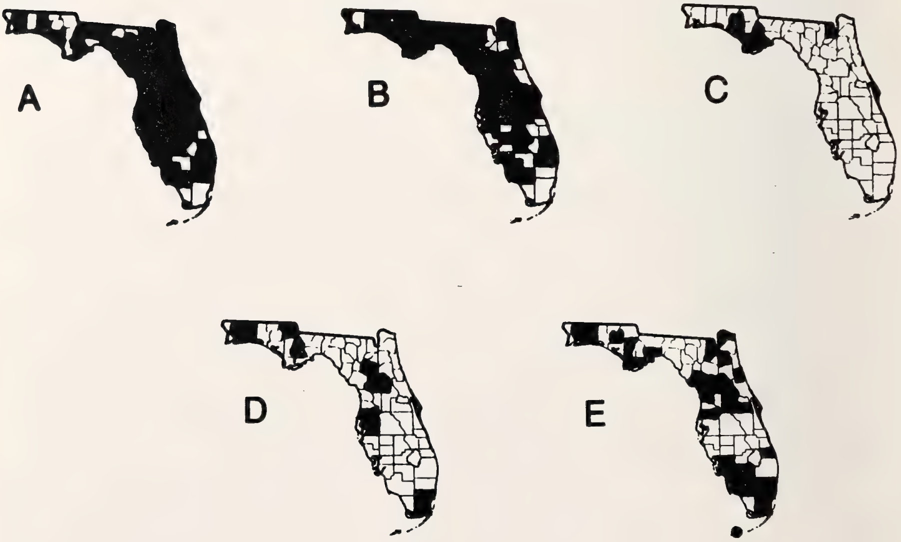

FIG. 3. Distribution of *Hypoxis* species in Florida as recorded by herbarium specimens. A. *H. juncea; B. H. leptocarpa; C. H. rigida; D. H. sessilis; E. H. wrightii.*

2. H. LEPTOCARPA (Engelmann & Gray) Small, Man. Southeastern Flora: 317. 1933. Basionym: *Hypoxis erecta leptocarpa* Engelmann & Gray, Boston J. Nat. Hist. 5: 27. 1845. Type: TEXAS, sandy soil near water courses, 1843, Lindheimer Flora Texana exsiccata 188 (holotype: MO; isotypes: GH, PH, US). *Hypoxis hirsuta* var. *leptocarpa* (Engelmann & Gray) Brackett, Rhodora 25: 127. 1923.

Hypoxis curtissii Rose in Small, Fl. Southeastern United States: 287, 1329. 1903. Type: FLORIDA, Duval Co., swamps near Jacksonville, 19 May 1894, A. H. Curtiss 4727 (holotype: US; isotypes: GH, NY).

Leaves several to many, glabrous or nearly so, flexible, W-shaped in cross section but appearing flat in pressed specimens. Narrowly triangular but often appearing widest above the middle in pressed specimens, 2-10 mm wide and 8-50 cm long. Bases of dead leaves never disintegrating into persistent fibers. Inflorescence with 1-3 (7) flowers, lowest two flowers (when present) not paired. Scape length (4) 5-13 (27) cm. Bracts (0.3) 0.5-2.0 (8.0) cm long, in larger plants the bracts are often fleshy and longer than the pedicel and flower they subtend. Pedicel (0.2) 0.5-1.2 (2.0) cm long. Sepals 0.4-0.8 (1.1) cm long, 0.05-0.21 cm wide. Anthers 1.0-1.8 mm long. Ovary cylindric, (0.2) 0.3-0.6 (0.7) cm long, 0.1-0.2 wide at top, approximately as long as the sepals. Capsule elliptic, 0.3-0.7 cm long, 0.2-0.3 cm wide. Seed 1.2-1.6 mm long, black, surface cells coarsely muricate.

H. leptocarpa is easily distinguished from other species of *Hypoxis* in Florida by a lack of pubescence and broad, thin leaves. The very long bracts found on many plants (Fig. 1b) are also unique to this species. It is not always so easy to recognize it as a *Hypoxis*, however, unless it is in flower. In life the leaves have a W-shaped cross-section that make them very difficult to distinguish from associated sedges.

The plant is found in wet sandy or organic soil along riverbanks throughout Florida (Fig. 3b). It is abundant in the Panhandle and northern half of peninsular Florida. Abundance appears to decrease rapidly in the southern half of the peninsula but it is probably missing only from Dade and Monroe counties at the southern tip of the peninsula.

Colonies tend to be dense, but limited in extent. Cultivated plants produce seeds without requiring pollination, and flowering occurs throughout most of the year, so large quantities of seed can be produced by individuals. This large seed output can be seen as an adaptation to the unstable habitat occupied by the colonies. Individual colonies are subject to frequent destruction through local flood conditions, so the continued existence of the species seems to require rapid and continuous establishment of new colonies.

3. HYPOXIS RIGIDA Chapman, Fl. Southern United States, ed. 2, Supplement 2: 696. 1892. Type: FLORIDA, without definite locality, Chapman s.n. (lectotype: US).

Leaves few to several, somewhat stiff, V-shaped in cross section but appearing flat on pressed specimens, (0.8) 1.0-2.0 (2.6) cm wide, 5-30 cm long; pubescent. Bases of dead leaves persisting, remaining attached to the stem and surrounding the live leaves, usually all but the outermost intact, infrequently breaking down to a dense fibrous crown. Inflorescence 1-2 (4) flowered. Scape (4) 6-13 (18) cm long. Bract (0.2) 0.3-0.5 (0.6) cm long, usually shorter than pedicel. Pedicel (0.2) 0.3-0.8 (1.5) cm long. Sepal 0.5-0.8 (1.0) cm long, 0.14-0.25 cm wide. Anthers 1.5-3.5 mm long. Ovary cylindric, 0.3-0.5 (0.7) cm long, 0.1-0.2 cm wide at top, about equal in length to the sepals. Capsule elliptic, 0.5-0.8 cm long, 0.3-0.4 cm wide. Seed 1.0-1.3 mm long, black, with rounded pebbling on the surface.

This species can usually be easily recognized by the presence of many dead leaf bases clothing the stem and leaf bases of the plants. In *H. wrightii* and *H. sessilis*, specimens will often have plant bases surrounded by fibrous remnants of two or three leaf bases, but in *H. rigida* the remnants of dozens of leaf bases remain and, usually, several dead leaf bases with very little appearance of decay are also found. If the specimen consists of leaves cut off at ground level, or dead leaf bases were removed from the specimen prior to mounting, it may be impossible to distinguish this species from *H. sessilis* and/or *H. wrightii*. Anther length, as given in the key, will usually work, but it is not completely accurate. The bract in *H. rigida* is usually much longer than in the other two species and often exceeds the pedicel. Specimens of *H. wrightii* in which the bract exceeds the pedicel in length have comparatively smaller flowers.

This species has the most limited distribution of all members of the genus in Florida. It has been reported from scattered localities in northern Florida (Fig. 3c). It is likely that the distribution of this species in Florida is considerably more extensive than shown. The most characteristic habitat seems to be nutrient-poor, seasonally-flooded *Sarracenia* bogs and adjacent pine flatwoods. *H. rigida* is also found along the side of roads running through or by those habitats.

Flowering patterns in the field are unknown. Plants in cultivation produce seed without pollination.

4. HYPOXIS SESSILIS Linnaeus, Sp. Pl., ed. 2, 1: 439. 1762. Type: Dillenius, Hortus Elthamensis 2: pl. 220, fig. 287.

Hypoxis longii Fernald, Rhodora 37: 410, pl. 393. 1935. Type: VIRGINIA, Princess Anne Co., damp sandy and peaty depressions back of the dune, Rifle Range, south of Rudy Inlet, July 30 and 31 and Aug 4, 1934, Fernald & Long 3862 (holotype: GH, isotypes: PH, US).

Leaves few to several, usually stiff, with a V-shaped in cross section in life, appearing flat in pressed specimens, 0.9-5 mm wide, 5-40 cm long; pubescent. Bases of dead leaves occasionally remaining attached to the stem and breaking down to persistent fibers. Inflorescence 1 (2)-flowered. Second flower (when present) not opposite the first. Scape length (3) 4-9 (14) cm. Bract (0.2) 0.3-0.7 (0.8) cm long, almost always equalling or slightly exceeding the pedicel. Pedicel length (0.2) 0.3-0.7 (0.8) cm. Sepal (0.6) 0.7-1.0 (1.3) cm long, 0.09-0.24 cm wide. Anthers 1.1-2.2 mm long. Ovary cylindric, (0.3) 0.4-0.5 (0.6) cm long, 0.1-0.2 cm wide at top, conspicuously shorter than sepals in most specimens, but may exceed the length of the sepals in specimens with cleistogamous flowers. Capsule elliptic, 0.4-0.8 cm long, 0.3-0.4 cm wide. Seed (1.3) 1.4-2.0 mm long, black but covered by a thin, iridescent, membranous coat, with rounded or truncated pebbling on the surface.

Hypoxis longii was specifically compared with *H. sessilis* in the original description (Fernald, 1935). It was considered to differ on the basis of cleistogamous flowers: Fernald specifically stated that *H. sessilis* always had chasmogamous flowers, while *H. longii* possessed only cleistogamous flowers. Most flowers produced by *H. sessilis* in Florida are cleistogamous (Herndon, 1988) with chasmogamous flowers being produced on the same plants at other times, so this distinction does not seem important.

Most herbarium specimens represent plants which are blooming shortly after a fire. At this time, the scapes are uncharacteristically long (Herndon, 1988). Inflorescences produced by the same plant later are much shorter and the flowers appear at ground level. Plants without open flowers are very difficult to see, so they are rarely collected. Plants collected during the first bloom after a fire are very difficult to distinguish from *H. wrightii* without seed. The most problematic specimens are those with bracts exceeding 2 mm in length. For there appearance of the inflorescences of the two species is nearly identical. The scapes of *H. sessilis* are usually notably thicker and the sepals longer than on *H. wrightii* with the same inflorescence size, but vegetative and/or floral characters insuring reliable separation of the two species have not been identified. Plants collected after the first flowering will usually have the short bract (1-2 mm) and can be identified as *H. sessilis* on that basis. See the discussion under *H. rigida* for distinctions from that species.

This species has been most often collected on the Coastal Plain, but several specimens (under the name *H. longii*) have been found considerably inland (Taylor and Taylor, 1981). The cryptic nature of the plant (Herndon, 1988), suggests it occurs over a much wider range than currently documented. It has been found in several counties scattered throughout Florida, including the tip of the peninsula (Fig. 3d). It undoubtedly occurs in many counties for which herbarium records are lacking. Typical habitat in northern Florida is *Pinus palustris* sandhill. In southern Florida it is also restricted to a frequently burned, well-drained pineland.

In the southern parts of its range, this plant can bloom at any time of year in response to an appropriate disturbance (usually fire). In the northern part of its range, there seems to be a yearly late spring bloom. Populations are typically small and scattered. Plants in cultivation produce seed without pollination.

5. **HYPOXIS WRIGHTII** (Baker) Brackett, Rhodora 25: 140. 1923. Basionym: *Hypoxis juncea* var. *wrightii* Baker, Jour. Linn. Soc. Bot. 17: 106. 1878. Type: CUBA, without definite locality, C. Wright 236 (holotype: K).

Leaves few to several, typically stiff, with a V-shaped cross section in life, appearing flat in pressed specimens, (0.5) 0.7-2.1 (2.6) mm wide, 5-40 cm long; pubescent. Bases of dead leaves frequently remaining attached to the stem and breaking down to persistent fibers. Inflorescences 1-2 (3) flowered. Second flower (when present), not opposite the first. Scape (2.0) 3.5-8.5 (15.0) cm long. Bract setaceous (0.2) 0.3-0.8 (1.5) cm long. Pedicel (0.1) 0.3-1.2 (2.1) cm long. Sepal 0.4-0.8 (1.0) cm long, (0.14) 0.20-0.30 (0.35) cm wide. Anthers (0.6) 0.9-1.8 (2.0) mm long. Ovary cylindric, (0.2) 0.3-0.6 (0.8) cm long, 0.1-0.2 wide, conspicuously shorter than the sepals in most specimens, but exceeding the sepals in specimens with cleistogamous flowers. Capsule elliptic, 0.4-0.8 cm long, 0.3-0.4 cm wide. Seed 0.9-1.1 (1.3) mm long, dark brown, surface minutely muricate.

The name *Hypoxis micrantha* Pollard was inappropriately applied to this species by Brackett (1923), and this usage has been followed by subsequent authors. Furthermore, Brackett treated plants from the southeastern United States as specifically distinct from very similar plants growing in the West Indies. I have been unable to find any differences between plants from these two areas, and regard them as a single species. *H. wrightii* was the first name applied to these plants with brown, finely muricate seed coats.

No singular floral or vegetative characteristics distinguish *H. wrightii* although the combination of a conspicuous bract shorter than the pedicel, flower (sepals + ovary) longer than the pedicel, and sepals only slightly exceeding the ovary in length is almost always associated with this species. It is most likely to be confused with specimens of *H. sessilis* collected shortly after a fire. See the discussion under that species for further distinctions.

This is the only species found in both the United States and the West Indies. It has been found throughout Florida, including the Lower Florida Keys, and will undoubtedly be found in many of the counties for which no records currently exist (Fig. 3e). It is found in frequently burned areas and, in southern Florida, is the first species to flower following fire. Suitable habitat ranges from seasonally flooded prairie or boggy pinelands to well-drained pinelands.

Flowering is most common late spring to summer, but plants may bloom at any time of year in response to appropriate disturbance (usually fire). Natural populations of this plant are small and scattered, but are frequently found along road shoulders. Plants in cultivation produce seed without pollination.

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Ramirez-Domenech and Sharon Matthews of Louisiana State University. Curators of the herbaria at the Arnold Arboretum, the Field Museum of Natural History, University of Florida, Florida State University, Gray Herbarium, University of Minnesota, Missouri Botanical Garden, New York Botanical Garden, Smithsonian Institution and University of South Florida have all been extremely helpful in either arranging loans or providing facilities during visits.

LITERATURE CITED

Brackett, A. H. 1923. Revision of the American Species of *Hypoxis*. Rhodora 25:120-147, 151-155.

Fernald, M. L. 1935. Midsummer vascular plants of Virginia. Rhodora 37:378-413, 423-453.

Herndon, A. 1988. Ecology and systematics of *Hypoxis sessilis* and *H. wrightii* (Hypoxidaceae) in southern Florida. Amer. J. Bot. 75:1803-1812.

Small, J. K. 1933a. *Hypoxis juncea*. Addisonia 18: pl. 578.

Small, J. K. 1933b. A Manual of the Southeastern Flora. Univ. of North Carolina Press, Chapel Hill, North Carolina.

Taylor, R. J. and C. E. Taylor, 1981. Biology and Distribution of *Hypoxis longii* Fern. (Amaryllidaceae). Bull. Torrey Bot. Club 108:482-484.

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EXOTIC CRANE IN PASCO COUNTY, FLORIDA—*George T. Eliason*,

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ABSTRACT: *An exotic crane* (Grus antigone) *was observed in Pasco County foraging with native sandhill cranes* (Grus canadensis pratensis). *This is the first record of this presumably escaped exotic bird in central Florida.*

THE basin marshes, pine flatwoods, and improved pasture, common in south central Pasco county, provide high quality nesting and foraging habitat for the Florida sandhill crane *(Grus canadensis pratensis)*. In one particular area, no fewer than three pairs of sandhill cranes had a successful 1989-1990 breeding season with each pair raising two young. During early spring of 1989 an exotic crane, the sarus crane, *(Grus antigone)* was observed foraging with the native sandhill cranes in an area of improved pasture, south of SR 52 and west of rangeline 17/18. The occurrence of the sarus crane is thought to be an escapee from one of several zoos in the region (Wells, 1990). Personal conversations with Wes Biggs (1990), director of the Florida Audubon's Breeding Bird Atlas, indicate there have been no previous reports of sarus cranes in central Florida.

The sarus crane was observed on several occasions with groups of 3 to 8 sandhill cranes during the courtship and nesting periods of November through February 1989/90. By March, however, the large exotic bird was foraging alone. Although pairing has been observed by the land owner, evidence of the mating of the sarus crane with native Florida sandhill cranes was not observed; however, the possibility should not be discounted.

The sarus crane, substantially larger than the sandhill crane, appeared to be the dominant animal when foraging in groups. Sandhill cranes seem to follow the larger crane's actions (flight response) when approached by man. None of the birds retreat before the sarus crane did so.

According to the local landowner, the sarus crane has been resident on his property for over 7 years. The landowner has seen the sarus crane produce two clutches in years past. Apparently the exotic crane had bred with local sandhill cranes. The offspring displayed the same full red head and upper neck which is characteristic of the sarus crane. The survival of the offspring is not known, although it was suggested that two were taken by alligators and that only one individual grew to fledgling size.

The sarus crane is native to southeast Asia. Standing 5 feet in height, the bird has a crimson red head and upper neck (King and Dickinson, 1975). The plumage is a pale grey to white, and the legs are pale pink.

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LITERATURE CITED

BIGGS, W. 1990. Breeding Bird Atlas Director, Florida Audubon. January, 1990. Pers. Communi.

KING, B. F., AND E. C. DICKINSON. 1975. A Field Guide to the Birds of South-East Asia. Collins. St. James Place. London. pp. 111-112.

WELLS, M. 1990. Curator of birds, Busch Gardens Florida. January, 1990. pers. comm.

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STUDIES OF THE FLORIDA CONVOLVULACEAE—V. *CALYSTEGIA*

Daniel F. Austin, Department of Biological Sciences, Florida Atlantic University, Boca Raton, Florida 33431

ABSTRACT: *Two species of* Calystegia *are known from Florida.* Calystegia catesbeiana *is a rare southeastern U.S. endemic, being known in the state from a single locality.* Calystegia sepium *ssp.* limnophila *is widespread in the state, extending from the southern tip of the peninsula into the western part of the Panhandle.*

SINCE *Calystegia* was originally separated from *Convolvulus*, it has had an array of proponents (Bentham and Hooker, 1876; Hallier, 1893; O'Donell, 1959; Brummitt, 1965; Lewis and Oliver, 1965; Radford et al., 1968; Wunderlin, 1982; Clewell, 1985; Mohlenbrock, 1990) and opponents (Gray, 1886; Kuntze, 1899; Small, 1933; Roberty, 1952; Macbride, 1959). Most botanists now agree that the available data are sufficient to justify generic separation of the species (Lewis and Oliver, 1965). *Convolvulus*, where *Calystegia* species have often been placed, is certainly similar, but distinct (Sa'ad, 1967). The differences between these two genera are in pollen, stigma types, and the presence or absence of foliose bracts below the flowers. *Calystegia* has pantoporate pollen, flattened, apically obtuse to rounded stigmas, and foliose bracts. *Convolvulus* has 3-colpate pollen, cylindrical or subulate stigmas with acute apices, and squamose bracts.

There are some 53 taxa of subspecific or higher rank in *Calystegia* (Brummitt, 1965, 1974, 1980), and about half of these are endemic to California. Florida has records for only two species; distribution is based on specimens deposited at the Fairchild Tropical Garden, Florida Atlantic University, Florida State University, University of Florida, Smithsonian Institution, and the University of South Florida.

Calystegia R. Brown, Prodr. 481. 1810. Type species: *C. sepium* (L.) R. Brown. *Convolvulus* sect. *Calystegia* (R. Brown) Bentham, Fl. Austral. 4: 428. 1868.

Vines, herbaceous, perennial; stems erect or sprawling and weakly branched, or twining and often branched, glabrous or pubescent. Leaves entire, ovate, reniform to sagittate, often acute or obtuse apically, obtuse to cordate or hastate basally, glabrous or pubescent. Inflorescences axillary, solitary or cymose. Flowers with subequal sepals surrounded and subtended by two foliaceous bracts larger than sepals, or the bracts remote and only slightly overlapping sepals; corollas campanulate or more commonly funnelform, glabrous or slightly puberulent on the margins of the limb, particularly at the apex of the interplicae; stamens included, subequal, the filaments with glandular trichomes basally, anthers sagittate basally; pollen spheroidal, pantoporate, non-spinulose; ovary ovoid, glabrous, 2-locular basally and 1-locular apically, 4-ovulate, the style 1, entire, glabrous, the two stigmas oblong, with blunt apices. Fruits capsular, ovoid to subglobose, enclosed within the bracts in some species, becoming unilocular; seeds glabrous, often subglobose to ovoid-trigonous, surface smooth or ornamented.

KEY TO SPECIES

a. Stems erect or trailing. Flowers from lower axils only .... *C. catesbeiana*

a. Stems twining. Flowers from upper and lower axils .... *C. sepium* ssp. *limnophila*

1. *Calystegia catesbeiana* Pursh, Fl. Amer. Sept. Suppl. 2:729. 1814. Type: in Carolina. *Catesby* in herb. Sherard (presumably OXF, not seen; concept used here follows annotations by Brummitt).

Convolvulus sericatus House, Torreya 6:150. 1906. *C. catesbeiana* ssp. *sericata* (House) Brummitt, Ann. Missouri Bot. Gard. 52:21 6.1965.Type: Georgia. Rabun Co. near Rabun Bald, 4 Jun 1906, *House 2270* (US!, NY).

Herbs; stems decumbent to ascending, rarely twining and then mostly at tips, simple or weakly branched. Leaves oblong-lanceolate to triangular, 3-5 cm (6-8 cm long elsewhere) long, apically acute to obtuse, basally lobed, the lobes divergent and rounded, glabrous to pubescent. Flowers axillary, solitary, from the lower leaf axils only; bracts ovate 20-21 mm (25-30 mm elsewhere) long, obscurely ribbed; corollas white, 4-5.1 cm (5-6 cm elsewhere) long and broad. Fruits not seen in Florida material, elsewhere said to be ovoid, 1 cm long.

Habitat is not often recorded for the species, but it has been found in nearby Georgia in mature *Pinus palustris-Aristida stricta* woodland that is frequently burned. This species has long been confused with *C. spithamea* (e.g., Clewell, 1985). Brummitt (1965) separated these back into the original concept of two species, although he also recognized a variant as ssp. *sericata*. Specimens in Florida are supposed to belong to both subspecies, although I find them impossible to separate and do not recognize the subspecies.

Two specimens are known from Florida. Jackson Co.: Marianna Caverns State Park, 22 Apr 1960, *Mitchell 141* (FSU). County unknown. without locality. *Chapman 186* (NY, annotated by Brummitt as ssp. *catesbeiana*). Specimens also exist for nearby areas in Georgia. Thomas Co. Tall Timbers Research, Inc., Wade Tract, 14 Apr 1988, *Anderson 11141* (FAU); 4 Jun 1988, *Anderson 11427* (FSU).

This rare endemic southeastern U.S. species ranges from the Carolinas south through Georgia to the Panhandle of Florida.

2. *Calystegia sepium* (L.) R. Brown ssp. *limnophila* (Greene) Brummitt, Ann. Missouri Bot. Gard. 52:216. 1965.

Convolvulus limnophilus Greene, Pittonia 3:29. 1898. Type: California. Suisun Marsh, Aug. 1883. *E. L. Greene 39709* (syntype ND fide Brummitt, in litt.).

Convolvulus sepium L., Sp. Pl. 153. 1753. Type: Europe. specimen 218.3 in herb. *Linnaeus* (LINN, not seen; microfiche !).

Convolvulus repens L., Sp. Pl. 158. 1753. Type: specimen 218.55 in herb. Linnaeus (LINN, not seen; microfiche!).

Convolvulus nashii House, Muhlenbergia 5:66. 1909. Type: Florida. Lake Co. Eustis. *Nash 609* (holotype Colombia Univ., not seen; isotype NY!).

Vines; stems softly and finely pubescent, twining. Leaves lanceolate to elliptic-lanceolate, 3-4 cm long, the apex acute to acuminate, basally sagittate, the lobes spreading. Flowers usually solitary in leaf axils; bracts ovate, 14-18 mm long, ribbed; corollas white or tinged pink on the limb and upper tube, 4-5 cm long. Fruits capsular, ovoid to globose, 1 cm long, 8-10 mm in diameter; seeds ovoid, 4-5 mm long, gray to black, smooth.

These plants are mostly found in swamp margins and marshes. The subspecies is widely distributed, being found in California, Nevada, New Mexico, Louisiana, Georgia, South and North Carolina, and Florida. Also found in northern Mexico and Peru (Brummitt, in litt.).

Florida specimens have been seen from Alachua, Bay Brevard, Broward, Citrus, Dade,Duval, Escambia, Franklin, Glades, Gulf Hendry, Highlands, Hillsborough, Jackson, Jefferson, Lake, Marion, Monroe, Palm Beach, Polk, Sumter, Taylor and Wakulla Counties. The narrow-leaved form was segregated as *Convolvulus nashii* House, but it grades into the other phena of the species and does not merit recognition. Segregation of *C. sepium* into subspecies by Brummitt (1965, 1980) appears to be a useful arrangement.

LITERATURE CITED

BENTHAM, G. AND J. D. HOOKER. 1876. Genera Plantarum 2: 874.

BRUMMITT, R. K. 1965. New combinations in North American *Calystegia*. Ann. Missouri Bot. Gard. 52:214-216.

———. 1974. A remarkable new species of *Calystegia* (Convolvulaceae) from California. Kew Bull. 29:499-502.

———. 1980. Further new names in the genus *Calystegia* (Convolvulaceae). Kew Bull. 35:327-334.

CLEWELL, A. F. 1985. Guide to the vascular plants of the Florida Panhandle. Univ. Presses of Florida, Tallahassee.

HALLIER, H. 1893. Versuch einer naturlichen Gliederung der Convolvulaceen auf morphologischer und anatomischer Grundlage. Bot. Jahrb. Syst. 16:453-591.

GRAY, A. 1886. Synoptical Flora of North America. 2(1):207-225, 433-436.

KUNTZE, O. 1899. Revision of Genera. 3:209-211.

LEWIS, W. H. AND R. L. OLIVER. 1965. Realignment of *Calystegia* and *Convolvulus* (Convolvulaceae). Ann. Missouri Bot. Gard. 52:217-222.

MACBRIDE, J. F. 1959. Convolvulaceae in Flora of Peru. Field Mus. Nat. Hist., Bot. Ser. 13(5):481.

MOHLENBROCK, R. H. 1990. The Illustrated Flora of Illinois. Flowering Plants, Nightshades to Mistletoe. pp. 72-102. Southern Illinois Univ. Press, Carbondale.

O'DONELL, C. A. 1959. Convolvulaceas americanas. Lilloa 29:299-311.

RADFORD, A. E, H. E. AHLES AND C. R. BELL. 1968. Manual of the vascular flora of the Carolinas. Univ. N. Carolina Press, Chapel Hill.

ROBERTY, G. 1952. Genera convolvulacearum. Candollea 14:11-60.

SA'AD, F. 1967. The *Convolvulus* species of the Canary Isles, the Mediterranean region and the Near and Middle East. Meded. Bot. Mus. Herb. Rijksun. Utrecht 181(1967):1-288.

SMALL, J. K. 1933. Manual of the Southeastern Flora. Univ. N. Carolina Press, Chapel Hill.
WUNDERLIN, R. P. 1982. Guide to the Vascular Plants of Central Florida. Univ. Presses of Florida at Gainesville, Univ. South Florida Press.

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REVIEW

Fred Berry and W. John Kress, *Heliconia–An Identification Guide*, Smithsonian Institution Press, Washington, D.C., 1991. Pp. viii+334. Price: $35.00 (cloth), $16.95 (paper).

As hard as I tried, I couldn't find anything to criticize in this gem of a book. As a professional taxonomist, I first looked for a taxonomic key and technical descriptions, but quickly realized that those tools would be nearly useless for the intended lay audience. Even for a taxonomist these large, colorful monocots are very difficult to characterize with conventional terminology. They share this problem with bromeliads, palms, bananas, pandans, orchids, gingers and so forth. In such cases, a picture truly is worth a thousand words. The photographs in this book are uniformly clear and brilliant, and are logically arranged according to inflorescence types, with a key-like marginal guide. Each is accompanied by a brief summary of the most important descriptive characters. Matches can be made much more quickly and with greater certainty, at least for the needs of the horticulturist, than could be done by struggling through a conventional key. Dr. John Kress, moreover, is recognized as *the* authority on *Heliconia* today, and so one can be assured that this volume is as accurate as current knowledge permits.

The supplementary chapters covering morphology, geography, breeding, collecting, conservation, etc. are also clear and informative. This book belongs on the shelf of anyone who loves plants, particularly horticulturists and gardeners in the tropics, as well as that of taxonomists and other scientists needing a tool for quickly and accurately identifying specimens of this most colorful and distinctive of tropical genera.—Frederick B. Essig, Department of Biology, University of South Florida, Tampa.

REGENERATION IN BURNED CYPRESS SWAMPS

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ABSTRACT: *Pondcypress (*Taxodium distichum *var.* ascendens*) swamps were studied to assess the impacts of fire on cypress regeneration. Transects were established in 1990 in swamps that were burned by wildfires in 1985, in swamps that were burned by prescribed fires in 1987, and in swamps with no recent fire history. Although basal sprout reproduction by cypress was common in the burned swamps, no seedlings were found. This suggests that other factors, such as hydroperiod, are important in regeneration of cypress swamps.*

THE long-term role of fire in swamps dominated by cypress trees *(Taxodium distichum)* is poorly understood. Evidence shows that cypress seedlings are shade-intolerant (Neufeld, 1983), that competition reduces seedling survivorship (Gunderson, 1984), and that seed production is enhanced in burned and sewage-enriched swamps (Deghi et al., 1980; Brown, 1981). It is possible, then, that regeneration in cypress ponds is stimulated by fire. The purpose of this study was to analyze regeneration in cypress swamps that had been burned by wildfire and by prescribed fire and to compare it with regeneration in unburned swamps.

METHODS—Nine cypress swamps at Austin Cary Memorial Forest in north central Florida were selected for study. Three were burned in 1985 by wildfire, three were burned in 1987 by prescribed fire, and three were undisturbed by recent fires.

The six burned swamps were smaller than the three unburned swamps, although none was larger than approximately 2 ha. Canopy density generally was lower in the burned swamps than in the unburned swamps. Virginia chain fern *(Woodwardia virginica)* was the dominant understory plant. All but two swamps (one wildfire-burned and one control-burned) contained standing water at the time of measurement (July 1990).

Cypress seedlings and sprouts 2 m tall or less were counted along three parallel 5-m-wide transects in each swamp. Sprouts and seedlings were manually and visually inspected at the roots to distinguish the two growth forms. The first transect intersected the lowest point (determined visually) in the center of the swamp. The second transect was established midway between the center and an edge of the swamp. The third transect was tangential to an edge of the swamp, which was discerned by the abrupt change in vegetation. Transect locations were determined at random.

RESULTS AND DISCUSSION—Although no seedlings were found in any of the swamps burned by wildfire or prescribed fire, sprouts were common (Table 1). Seedlings were found growing along the edges of two of the three unburned swamps, where water depth is relatively shallow and light penetration is greater. If seedlings had been produced in the burned swamps, none survived. In addition to reproduction by seed, regeneration by basal sprouting is an important means of reproduction in cypress swamps and is known to occur following harvest or fire (e.g., Ewel et al., 1989). In this study, as many as nine sprouts were observed on a single stump, although only one or two may eventually reach the canopy.

The lack of cypress seedlings in the burned swamps suggests that fire may not be the only factor that promotes sexual reproduction. Seedling survival depends on many factors, including hydroperiod and depth of water inundation, exposure to drought, temperature, light intensity, and soil conditions (Brandt and Ewel, 1989). Any one of these conditions can adversely impact the production and survival of young seedlings. Water level fluctuations in the area due to artificial drainage may have had an effect as well. The recent installation of drainage ditches undoubtedly changed hydroperiods and runoff patterns. The immediate impact of these changes on cypress reproduction are not apparent, however. Germination success is not likely to have decreased because of drainage, because cypress seeds do not germinate under water anyway (Demaree, 1932). Rainfall the following fall and winter was above normal, so seeds that fell that year should have been well soaked, and rainfall was only 12% below normal the following year. Nor was there any indication of a shift in dominant species that might have increased competition for young seedlings.

TABLE 1. Transect area and average number of sprouts and seedlings for each swamp type sampled

Swamp Type	Total Area Sampled (m^2)	Sprouts/m^2	Seedlings/m^2
A. Wildfire			
Swamp A-1	775	0.050	0
Swamp A-2	375	0.029	0
Swamp A-3	375	0.048	0
Mean		0.042	0
SE		0.001	0
B. Prescribed fire			
Swamp B-1	700	0.003	0
Swamp B-2	640	0.005	0
Swamp B-3	755	0.048	0
Mean		0.019	0
SE		0.004	0
C. Unburned			
Swamp C-1	1,605	0	0.019
Swamp C-2	975	0	0
Swamp C-3	815	0	0.004
Mean		0	0.007
SE		0	0.002

Evidence showing that fire often increases cone production in cypress and can increase the survivorship of cypress seedlings by decreasing competition suggests that fire can be an important factor in cypress reproduction. On the other hand, severe fire was correlated with lack of cypress reproduction in one of nine swamps that were surveyed after clearcutting (Ewel et al., 1989), but in these swamps no aboveground cypress biomass remained at all. Because neither wildfires nor prescribed fire in the six swamps in this study resulted in cypress seedling production, it may be concluded that cypress reproduction depends on a variety of factors, and that fire may sometimes be important. Hydroperiod, with water levels periodically dropping low enough to allow germination and rising high enough to prevent invasion by competing species, may also contribute to cypress reproduction success and seedling survival, but the pattern of cypress reproduction is still not well understood.

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LITERATURE CITED

BRANDT, K., and K. C. EWEL. 1989. Ecology and management of cypress swamps: a review. Fla. Coop. Ext. Serv., Inst. Food Agric. Sci., Univ. Fla., Gainesville. Bull. 252.

BROWN, S. 1981. A comparison of the structure, primary productivity, and transpiration of cypress ecosystems in Florida. Ecol. Monogr. 51:403-427.

DEGHI, G. S., K. C. EWEL, AND W. J. MITSCH. 1980. Effects of sewage effluent application on litter fall and litter decomposition in cypress swamps. J. Appl. Ecol. 17:397-408.

DEMAREE, D. 1932. Submerging experiments with *Taxodium*. Ecology 13:258-262.

EWEL, K. C., H. T. DAVIS, and J. E. SMITH. 1989. Recovery of Florida cypress swamps from clearcutting. South. J. Appl. For. 13:123-126.

GUNDERSON, L. H. 1984. Regeneration of cypress in logged and burned strands at Corkscrew Swamp Sanctuary, Florida. Pp. 349-357. *In*: EWEL, K. C. AND H. T. ODUM (eds.). Cypress Swamps. Univ. Presses of Florida, Gainesville.

NEUFELD, H. S. 1983. Effects of light on growth, morphology, and photosynthesis in baldcypress (Taxodium distichum (L.) Rich.) and pondcypress (T. ascendens Brongn.) seedlings. Bull. Torrey Bot. Club 110: 43-54.

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EMPLOYMENT OF WOMEN IN FLORIDA'S ORNAMENTAL HORTICULTURE INDUSTRY[1]

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ABSTRACT: *A survey of owners/operators of ornamental horticulture firms was conducted to determine the employment patterns of men and women. Results from employers representing over 3,000 workers indicated that men and women are concentrated in different types of jobs and sectors of the industry. Implications of the findings are discussed.*

IN the past decade, considerable research attention has been given to women's work on family farms (Haney and Knowles, 1989). Relatively little research has been conducted on women who are employed on larger-than-family enterprises, even though larger farms account for an increasing share of all agricultural production (Sachs, 1987; Bradshaw and Blakely, 1979). In addition, the percentage of women being awarded bachelor's degrees in agriculture has increased (Blau and Ferber, 1986), signaling the greater professionalization of women's participation in agriculture. Little is known, however, about the employment opportunities and constraints they face.

Research from the non-agricultural sector indicates that the proportion of women in the labor force has increased dramatically and that women are opting for more full-time work force participation (U.S. Department of Labor, 1989a). However, women and men in business and industry tend to be employed in separate spheres, with women concentrated in lower paying and support jobs that offer little opportunity for advancement. Women work in different occupations than men, primarily in occupations that are female-dominated, such as secretaries, elementary school teachers, bookkeepers, cashiers, office clerks, and nurses (Hartmann, Kraut, and Tilly, 1986, p.20). Women are less likely to be in senior management positions and more likely to be in skilled administrative support positions. In 1989, women held 40% of executive, administrative, and managerial jobs and 80% of administrative support jobs (Crispell, 1991; U.S. Department of Labor, 1990). Clerical occupations have become more female dominated in recent years and remain the anchor of women's jobs, employing almost 31% of all women workers in 1989 (Bielby and Baron, 1984; Crispell, 1991; Haddad, 1987; Hartmann, Kraut and Tilly, 1986, p.20). Women in clerical jobs earn 70% as much as men in similar positions (Crispell, 1991).

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Although women have gained experience and seniority in the last two decades, and although by the year 2000 they will make up nearly half the labor labor force, women are not expected to hold top managerial positions. Women represent less than 1% of the highest paid officers of the U.S. service and industrial companies and only 5% of upper level managers. (Fierman, 1990). The income gap is greatest in managerial positions. Women in full-time managerials jobs earn 61% as much as male managers (Crispell, 1991).

Within the same business, men and women often have different opportunities, such as access to on-the-job training and promotion (Roos and Reskin, 1984). Because women are often responsible for most family care (child care, elder care, and housework) they may be unable to take advantage of workplace opportunities. They may be unable to travel or to relocate, or to participate in educational programs that might lead to promotions or salary increases (Hartman, Kraut, and Tilly, 1986).

In addition, employer attitudes toward and treatment of female employees may limit women's opportunities. Employers expect women to conform to certain standards of femininity based on stereotypes of what is appropriate behavior for women and what is needed for success in a male-dominated system (e.g., not to aggressive but not too "soft") (Fierman, 1990). Employers also assume that women have higher turnover rates and are less committed to their jobs. Consequently, employers may give preferential treatment to men or eliminate women's jobs rather than considering ways work can be reorganized more equitably or what can be done to support both men's and women's work and family roles. Employers and the U.S. government have been slow to establish family supportive policies such as flextime, childcare, and parental care (Immerwahr, 1984. McNeely and Fogerty, 1988), despite the fact that research shows that the provision of employer-sponsored family benefit programs has positive effects on performance, retention, and morale (Youngblood and Chambers-Cook, 1984; U.S. Department of Labor, 1989b).

Social scientists know surprisingly little about job segregation by sex (Bielby and Baron, 1984) and most of the research that has been done has been focused on services, manufacturing, and business. There is some evidence that in both U.S. and Florida agriculture, women's clerical employment is increasing (Audirac, 1988; Hartmann, Kraut and Tilly, 1986) and that women hold a variety of positions in all aspects of Florida's agribusiness operations (Gladwin, 1985). However, attention has seldom been given to occupational segregation in agricultural industries, and for the most part it is not known whether Florida women are *concentrated* in certain types of jobs, how their occupational status *compares* with their male counterparts, or the implications of this occupational structure for women's opportunities for advancement.

Without such information about the basic structure of the labor force, it will be impossible for agribusiness employers to assess the composition of their firms, to increase efforts to employ qualified women, or to develop programs that would facilitate women's opportunities for advancement. This information is likely to become increasingly important to employers concerned with attracting and retaining a skilled agricultural labor force and improving employee productivity and performance. As women continue to increase their labor force participation in record numbers, information about their representation in the industry will be beneficial to future planning.

Ornamental horticulture is one of the three most important agricultural industries in Florida, based on gross earnings, and is a major contributor to the state's economy. Although previous studies have provided valuable information concerning patterns of employment and training (Ingram and Strain, 1984), the structure of the industry has not been identified. The objective of the research reported here was to describe the occupational structure of the Florida ornamental horticulture industry by gender. That is, this research describes the distribution of men and women in four occupational categories: managers/supervisors, clerical workers, and skilled and unskilled laborers. It was hypothesized that women would be more likely than men to be concentrated in clerical and skilled labor positions, while men would be more likely than women to be in administrative/supervisory jobs. However, because the industry is composed of both small firms and large-scale operations, we also examined the occupational structure of the labor force by size of operations. It was hypothesized that women in larger enterprises would be more likely than men to be concentrated in jobs as clerical workers and skilled laborers. It was hypothesized that men in larger firms would be more likely than women to be concentrated in administrative and supervisory roles. Also, it was hypothesized that there would be no difference between men and women in employment status as part-time, full-time, or seasonal workers. It was expected that women employed in smaller enterprises would be more likely than women in larger enterprises to be represented at the managerial levels. This hypothesis was based on the assumption that, even with limited resources, women in small firms might find it possible to own the business or to share a partnership with their husband.

METHODS—A stratified random sample of 516 nurseries was drawn from the Florida Department of Agriculture and Consumer Services' Certified Nursery Directory. The sample included 6% of all nurseries listed in the Directory. The sample was stratified on the basis of size, as defined by the number of plants produced. The Nursery Directory delineates ten sizes of nurseries, ranging from 1 to 10. The sample included 180 nurseries in sizes 1 through 8, the smaller nurseries that we call Size Class A; and 336 nurseries in sizes 9 and 10, the larger nurseries that we call Size Class B. A larger percentage of nurseries in sizes 9 and 10 were sampled because these firms could be expected to account for a relatively large percentage of the labor force within the industry. The sample included two-thirds of all certified firms in sizes 9 and 10, and 2.5% of all firms in sizes 1 through 8.

A one-page survey and a cover letter were mailed to the owners of selected firms, who were asked to complete the survey with information about their company's labor force. Employers were asked to estimate the number of men and women employed in the following occupational categories: managers/supervisors, clerical workers, skilled laborers, and unskilled laborers. Employers were also asked to indicate the number of men and women employed in part-time, full-time, and seasonal positions.

A total of 142 completed questionnaires were returned, for a response rate of almost 30%. Data were analyzed using percentages and the chi square statistic. It is difficult to explain the low response rate, particularly because individual contacts were made with some firm owners, apprising them that the survey was forthcoming and encouraging their participation; follow-up reminder post cards also were mailed. Possibly, firm owners were cautious about releasing any information pertaining to their labor force due to concerns about investigations of compliance with various labor laws. However, given the exploratory nature of this research and the lack of previous work in this area, the study findings do offer valuable information about the structure of the ornamental horticulture industry that can serve as a foundation for future research.

RESULTS—This report provides data on 3,106 workers employed in 142 nurseries. Forty-three percent (1,322) of the employees in the sample were women. In the sections that follow, three dimensions of employment will be discussed: (a) employment status, (b) occupational category, and (c) size class.

Employment Status—The vast majority of all workers in the sample were full-time employees. Seasonal employees constituted a higher percentage of the work force than part-time employees. Of the total of 3,106 employees in the survey, 82% were full-time, 6% were part-time, and 12% were seasonal. Women and men were almost equally represented as full-time workers, 82% of all women and 81% of all men. A slightly higher percentage of women workers than of men workers were part-time employees. A slightly lower percentage of women workers than men workers in the sample were seasonal employees (see Table 1).

TABLE 1. Employment status by total labor force and sex of worker

Employment Status	All Employees %	All Employees n	Women %	Women n	Men %	Men n
Full-time	82	2,529	82	1,077	81	1,445
Part-time	6	199	8	106	6	107
Seasonal	12	378	11	139	13	232

Occupational Categories—The distribution of men and women across occupational categories is found in Table 2. Fourteen percent (n=435) of the work force were employed in managerial and/or supervisory positions. Men outnumbered women in managerial positions, accounting for 64% of all managerial positions in the survey, while women made up only 36% of managers. Seven percent (n=217) of the work force was employed in clerical positions. Ninety-two percent of the clerical workers were women, whereas 8% were men. Eighteen percent (n=559) of the work force were employed as skilled labor. Of these, 60% were men and 40% were women. Nearly two-thirds of the work force (n=1,137) were employed as unskilled labor. Of these, 40% were women and 60% were men.

TABLE 2. Occupational category by sex of worker

Occupational Category	% Men		% Women	
Managerial	64	278	36	157
Clerical	8	17	92	200
Skilled	60	335	40	224
Unskilled	60	1,137	40	758

Chi-square analysis showed that there were significant differences (p=0.01) between women and men employees with regard to occupational category. Women were less likely than men to hold positions in managerial and unskilled labor jobs and women were more likely than men to hold clerical positions. Gender differences in employment in skilled jobs were not significant.

Size Class—The overall representation of male and female employees did not differ significantly by size class of nursery. Women accounted for 41% of the employees in Size Class A (smaller) nurseries and 42% of the employees in Size Class B (larger) nurseries, which reflects their participation in the labor force, i.e., 43% of all workers in the sample. Similarly, men accounted for 59% of all employees in Size Class A nurseries and 57% of all employees in Size Class B nurseries, again reflecting their labor force participation, i.e., 57% of all employees in the sample.

Turning to the employment status of workers in large and small firms, chi-square analysis indicated that employment of full-time, part-time, and seasonal workers *did* vary significantly (P=0.01) by size class of nursery. Size Class A nurseries employed relatively fewer full-time workers than Size Class B nurseries. In the smaller Size Class A nurseries, 60% of all employees worked full-time, whereas 82% of all employees in the larger Size Class B nurseries were full-time workers. On the other hand, Size Class A nurseries hired relatively greater numbers of both part-time and seasonal workers than did Size Class B nurseries. In Size Class A nurseries, 20% of all employees worked part-time and 20% were employed on a seasonal basis, whereas in Size Class B nurseries 4% of all employees were part-time and 14% were seasonal workers.

The employment status of women and men *did* vary significantly by nursery size class. In the smaller nurseries, women accounted for a lower percentage of full-time employees than predicted (P=0.05) and for a higher percentage of part-time employees than predicted (P=0.01). The participation of women as seasonal employees in Size Class A nurseries *did not* vary significantly from predicted values. In Size Class B nurseries no significant differences (P=0.05) between women and men were found in relation to employment status as full-time, part-time, or seasonal workers (see Fig. 1).

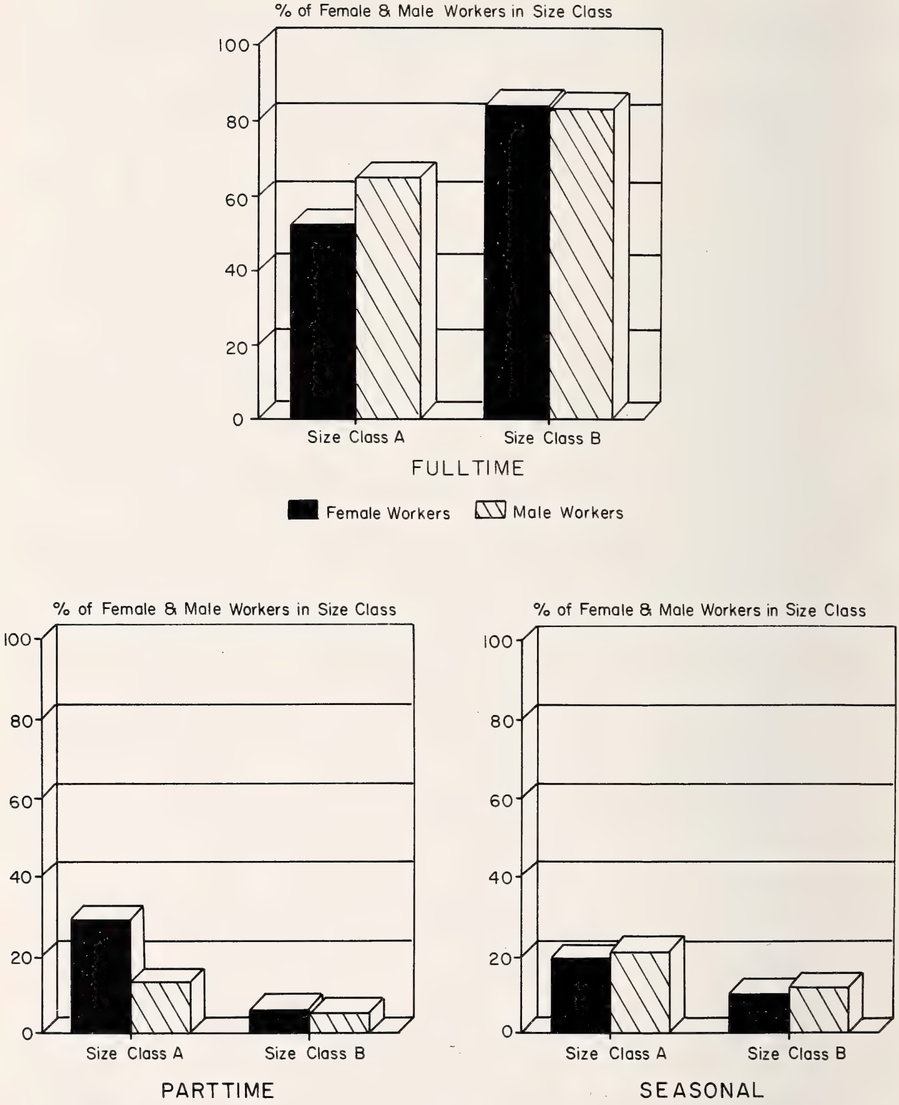

FIG. 1. Employment Status by Sex of Worker and Size Class of Nursery.

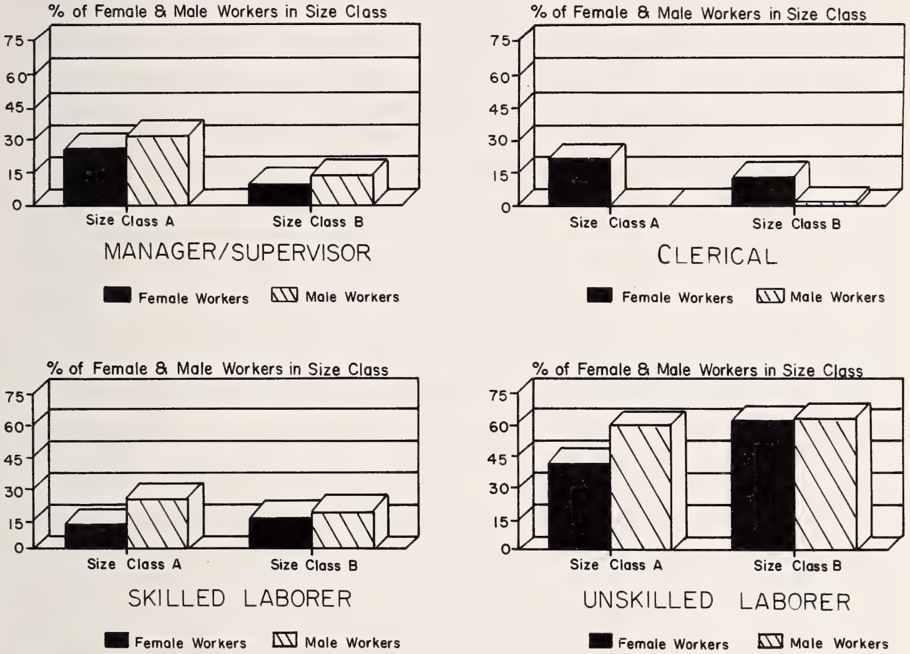

FIG. 2. Employment Class by Sex of Worker and Size Class of Nursery.

Patterns of men's and women's employment in occupational categories—as managers or supervisors, clerical, and skilled and unskilled laborers—also varied significantly by size class. The smaller nurseries employed a relatively larger number of managers or supervisors than did larger nurseries (p=0.01). In Size Class A nurseries, 24% of all employees were managers/supervisors, whereas only 11% of all employees in Size Class B nurseries fell in this category. They employed, however, a smaller number of unskilled laborers than predicted (p=0.01). Unskilled laborers accounted for 65% of all employees in the larger Size Class B nurseries, but only 49% of all employees in the smaller Size Class A nurseries. Employment of clerical workers and skilled laborers did not differ significantly by size class of nursery.

Employment patterns of men and women differed within the two size classes in relation to occupational category (Fig. 2). In the larger, Size Class B nurseries, employment patterns for women were the same as those for the sample as a whole: Women were under-represented as managers and unskilled workers and over-represented as clericals. In the smaller Size Class A nurseries, women were still over-represented as clerical workers (P=0.02), but there were no significant differences between the employment of women and men in any other occupational category.

Workers in the sample were concentrated in those nurseries employing more than 30 full-time workers. These nurseries accounted for over half (55%) of all employees in the sample, although they accounted for only 17% of all nurseries in the sample. Further, employment of women was significantly related to the number of full-time employees in the nursery (p=0.01). Compared to men, women were over-represented in nurseries which employ only 1 to 10 full-time workers and were underpresented in nurseries which employ more than 30 full-time workers.

Conclusions—This research was focused on employment patterns in the ornamental horticulture industry in Florida. The first goal was simply to describe the occupational patterns that exist, particularly as they are related to gender. The following results have important implications for employers: (a) the industry is made up primarily of full-time employees, (b) women are underrepresented in large nurseries, and (c) women are under-represented in managerial positions in all nurseries. These findings have important implications for programs designed to help women attain better, more stable jobs and suggest several areas where further research is needed.

First, full-time employees are undoubtedly the most important segment of the labor force in the ornamental horticulture industry in Florida. Unlike some other agricultural industries in Florida where part-time and seasonal employment is much higher, such as vegetable crop production, full-time employment in ornamental horticulture appears to be the norm. As these findings show, the vast majority of men and women in the sample were employed in full-time positions. However, the size of the firm does affect the percentage of workers with full-time status. The smaller nurseries hire relatively fewer full-time workers than do larger nurseries; and women account for a lesser percentage of full-time employees within smaller nurseries than predicted.

Results suggest that further research about employment patterns in the ornamental horticulture industry should probably focus on full-time employees and the factors associated with their performance and commitment to the industry, such as job satisfaction and needs for training and other assistance. With women concentrated in clerical positions, there may be a particular need to examine the impacts of improved information technologies on job pressure and quality, as these are likely to affect women's job satisfaction and commitment to the industry. In addition, research may also be conducted to determine the most effective ways of introducing technologies and structuring their work tasks and environment so as to attend to employees' needs as well as the firm's economic considerations (Hartmann, et al., 1986).

Findings also indicate that women are relatively underrepresented in the largest nurseries, those with over 30 full-time employees. The causes of this employment pattern remain unexplained, and further research should be conducted to determine why women tend to work in nurseries employing fewer full-time workers. This could be the result of the employment preferences of women, who, for example, may work reduced hours to meet caregiving responsibilities; or due to greater flexibility of work hours in smaller firms. However, research on the nonagricultural sector indicates that although many women would prefer to work part-time to have more hours with their children, few can afford this option. Part-time employment not only reduces family income but usually does not include essential benefits, such as health care and sick leave, and limits women's opportunities for advancement (Hoffmann, 1987). Thus, the causes of women's tendency to work in nurseries with fewer full-time workers could also be attributed to the structure of the labor force, i.e., fewer opportunities for women within the larger firms, than to women's employment preferences.

Additional research would determine whether fringe benefits vary between larger and smaller nurseries, specifically, whether larger nurseries offer more fringe benefits for full-time employees than do smaller nurseries. Similarly, salaries may vary with nursery size, as may stability of employment. If so, women's concentration in smaller nurseries would tend to indicate that women are working under sub-optimal conditions within the industry. This may be occurring at the very time that non-agricultural employers are developing guidelines for building a concern for people into an office technology plan (Hartmann, et al., 1986, p.153); and are establishing family supportive benefits and improving salaries that facilitate women's work performance and family responsibilities. Ultimately, these policies appear to affect a company's ability to attract and retain a qualified female labor force (U.S. Department of Labor, 1989b). Additional research on the dynamics of women's employment within the ornamental horticulture industry could explain how employment patterns in the industry determine women's earnings, access to fringe benefits, opportunities for stable employment, and chances for advancement.

The findings of this study clearly demonstrate that men significantly outnumber women in management positions. Considering that women now represent over half of college majors in ornamental horticulture at the University of Florida (the state's largest agricultural training institution), these results suggest that there may be barriers to women's employment, not only in the bigger, more powerful corporations but in higher-level positions.

As women increase their share of the ornamental horticulture labor force, agricultural employers will be faced with decisions regarding the employment and retention of a trained female labor force. This study provides evidence that the employment patterns of men and women in the industry do differ, and suggests possible explanations for these findings. Additional research is needed to identify the factors that facilitate or restrict women's movement into full-time employment in managerial positions, particularly in large industries. This research could provide the basis for policies and programs that would improve the quality of the work environment and employment experience, resulting in overall gains for women and beneficial results for employers.

LITERATURE CITED

AUDIRAC, I. 1988. The Automation of the Farm Office: The Impacts of High Tech Farming on Women. Paper presented at the annual meeting of the Rural Sociological Society, Athens Georgia.

BLAU, F. D. AND M. A. FERBER. 1986. The Economics of Women, Men, and Work. Prentice-Hall, Englewood Cliffs, N.J.

BIELBY, W. AND J. BARON. 1984. A women's place is with other women: Sex segregation within organizations. Pp.27-55. In Reskin, B. (ed.), Sex Segregation in the Workplace: Trends, Explanations, Remedies. National Academy Press, Washington, D.C.

BRADSHAW, T. K. AND E. J. BLAKELY. 1979. Rural Communities in Advanced Industrial Society. Praeger, New York.

CRISPELL, D. 1991. Women's earnings gap is closing-slowly. Am. Demogr. 13:14.

FIERMAN, J. 1990. Why women still don't hit the top. Fortune: 122(3):40-62.

GLADWIN, C. 1985. How Florida Women Help Farm and Agribusiness Firm Survive (Circular 613). Univ. Florida, Florida Coop. Extension Serv., IFAS, Gainesville, Florida.

HADDAD, C. 1987. Technology, industrialization, and the economic status of women. Pp. 33-57 *In:* WRIGHT, B., M. FERREE, G. MELLOW, L. LEWIS, M.D. SAMPLER, R. ASHER, AND K. CLASPELL (eds.), Women, Work, and Technology. Ann Arbor, Michigan, The University of Michigan Press.

HANEY, W. G. AND J. B. KNOWLES. 1989. Women and Farming: Changing Roles, Changing Structures. Westview Press, Boulder, Colorado.

HARTMAN, H. J., R. E. KRAUT, AND L. A. TILLY. 1986. Computer Chips and Paper Clips: Technology and Women's Employment. National Academy Press, Washington, D.C.

HOFFMANN, L. 1987. The effects on children of maternal and paternal employment. Pp. 362-395. *In:* GERSTEL, N. AND H.E. GROSS (eds.), Families and Work. Temple Univ. Press, Philadelphia.

IMMERWAHR, J. 1984. Building a consensus on the child care problem. Person. Admin. 29:31-38.

INGRAM, D. L. AND O. R. STRAIN. 1984. Central and South Florida Nursery Characteristics (Circular 593). Univ. Florida, Florida Coop. Extension Serv. IFAS, Gainesville, Florida.

MCNEELY, R. AND B. FOGERTY. 1988. Balancing parenthood and employment: Factors affecting company receptiveness to family-related innovations in the work place. Family Rel. 37:189-195.

ROOS, P. AND B. RESKIN. Institutional factors contributing to sex segregation in the work-place. Pp. 235-260. *In:* RESKIN, B. (ed), Sex Segregation in the Workplace: Trends, Explorations, Remedies. National Academy Press, Washington, D.C.

SACHS, C. 1987. American farm women. Pp. 233-248. *In:* STROMBERG, A.H., L. LAURWOOD, AND B.A. GUTAK (eds.), Women and Work, Vol. 2. Sage Press, Newbury Park, California.

U.S. DEPARTMENT OF LABOR. 1989a. Employment in Perspective: Women in the Labor Force. Fourth Quarter, Report 782. U.S. Department of Labor, Bureau of Labor Statistics, Washington, D.C.

. 1989b. Employers and Childcare: Benefiting Work and Family. U.S. Department of Labor, Women's Bureau, Washington, D.C.

. 1990. Employment in Perspective: Women in the Labor Force. Third Quarter, Report 796. U.S. Department of Labor, Bureau of Labor Statistics, Washington, D.C.

YOUNGBLOOD, S. A. AND K. CHAMBERS-COOK. 1984. Childcare assistance canimprove employees attitudes and behavior. Perso. Admin. 29:45-47.

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REVIEW OF THE EFFECTS OF FIRE ON *PEROMYSCUS* AND *PODOMYS*

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ABSTRACT: *Fires—both prescribed burns and lightning strikes—are common phenomena in the United States, particularly in the south. However, there have been few attempts to examine long-term effects of artificial or natural fires on small non-game mammals. Published reports of the effects of fire on mice of the genera* Peromyscus *and* Podomys *are summarized herein. Most papers described response of* P. maniculatus, *whose numbers increased on burned areas in forests and grasslands. Responses to fire differed among other species and habitats.*

PRESCRIBED burning is a tool used by land managers to sustain a particular type of forest or savanna. Frequently the ultimate goal is to maintain populations of special interest: game and forestry species or threatened and endangered species. For example, in 1982 the Forest Service burned approximately 81,000 ha in the Southeast Region alone to enhance habitats used by the red-cockaded woodpecker *(Picoides borealis)* (U.S.D.A. Forest Service, 1984). Given these goals, it is not unexpected that the majority of studies that examine how animals are affected by fire have concentrated on one species of interest, such as quail or white-tailed deer, and have not examined effects on less conspicuous species or on the fauna as a whole.

Before 1955, there was little interest in the effects of fire on small mammals (Taylor, 1981). Williams (1955) and others had noted differences in the local distribution of rodents following fires and other disturbances. Many of the early papers about fire and populations of small, non-sciurid rodents reflected the forester's interest in rodents as consumers of seeds and seedlings (e.g., Moore, 1940; Garman and Orr-Ewing, 1949; Fowells and Schubert, 1951; Spencer, 1955).

This paper considers the effects of fire on two genera of North American rodents. Ecology of mice of the New World genus *Peromyscus* (Muridae: Sigmodontinae) has been the subject of several reviews (Baker, 1968; Stickel, 1968; Terman, 1968; Kaufman and Kaufman, 1990). However, although the biology of these animals is well understood compared with that of other small rodents, there has been no concensus regarding response of peromyscine rodents to fire and references are scattered throughout mammalogical and forestry literature. Of special interest is the ecology of the Florida mouse, *Podomys floridanus* (formerly *Peromyscus floridanus*), a species endemic to Florida and currently listed as a Species of Special Concern (Florida Game and Fresh Water Fish Commission, 1987).

General effects of fire on mammals were reviewed by Bendell (1974), Lyon et al. (1978), Wright and Bailey (1982), Peek (1986), and Landers

(1987). Kiltie (1989) summarized the annual occurrence of wildfires in the central and eastern United States. Kaufman et al. (1990) thoroughly reviewed effects of fire on insectivores and small rodents (including *P. leucopus* and *P. maniculatus)* inhabiting grasslands. Jones (1990) independently summarized effects of fire on *Peromyscus* as reported for several habitats. This paper provides a review of the current literature (through 1990) on the effects of fire on *Peromyscus* and *Podomys* throughout the United States and Canada. Taxonomy in this paper follows that of Carleton (1990).

Effects of fire on *Peromyscus*.—A literature search yielded 38 papers in which the effects of fire on *Peromyscus* were specifically examined (Table 1). Most studies included trapping pre- and post-burn, but most trap sessions were of short duration (<=30 months). Intensity, area, and seasonality of fires varied. Five papers (Cook, 1959; Krefting and Ahlgren, 1974; Layne, 1974; Buech et al., 1977; Lowe et al., 1978) described effects of wildfires and 33 involved prescribed burns. Asterisks (Table 1) indicate 13 papers in which study areas were affected by other treatments (logging, chopping, clearcutting, or mowing) in addition to fires. In several additional reports not included in Table 1 (Rice, 1932; Vogl, 1973; Koehler and Hornocker, 1977; Bock and Bock, 1978; Erwin and Stasiak, 1979; Vacanti and Geluso, 1985), general observations regarding responses of *Peromyscus* to fires were indicated. Price and Waser (1984) examined post-fire abundance of rodents, including *P. eremicus* and *P. maniculatus*, in sage scrub.

Mortality of *Peromyscus* due to fire rarely has been observed. Tevis (1956*b*) described a slash burn in Douglas fir clearcuts in which logs and other debris produced a smoky, intense burn. He observed wood rats *(Neotoma fuscipes)* perishing in the blaze and assumed mortality of deer mice *(P. maniculatus)* and piñon mice *(P. truei)* based on recovery of only 32% of the animals marked before the burn. Chew and co-workers (1959) identified two carcasses as *Peromyscus* sp. after a fire in chaparral in Lechuza Canyon, California. Harty et al. (1991) discovered 57 dead meadow voles *(Microtus pennsylvanicus)* and one masked shrew *(Sorex cinereus)* after a prescribed grassland burn; they found no dead *Peromyscus* and trapped only three *P. leucopus* in 19 months of post-burn trapping. Horn (1938), Arata (1959), Tester (1965), Beck and Vogl (1972), Erwin and Stasiak (1979), Hedlund and Rickard (1981), and Peek (1986) all noted that small mammals can survive fires by remaining in burrows. Bigham and co-workers (1964) observed "small rodents" fleeing a fire in Oklahoma. Price and Waser (1984) noted that both hole-nesting and above-ground-nesting species declined in abundance in burned sage scrub.

Most projects listed in Table 1 were short-term studies of deer mice *(P. maniculatus)*, which showed a positive response to fires in almost all habitats. Population increases of *P. maniculatus* have been attributed to changes in food, particularly seeds and insects (e.g., Tevis, 1956*a*; Ahlgren, 1966; Krefting and Ahlgren, 1974; Bock and Bock, 1983; Gunther et al., 1983;

TABLE 1. Responses of *Peromyscus* and *Podomys* to fire. R=response (I=increase, D=decrease, 0=no response) and Time is the duration of the study (in months). Asterisk indicates application of treatment (logging, clearcutting, chopping, or mowing) in addition to fire.

State	Habitat	R	Time	Reference
P. californicus				
CA	mixed brush	D	30	Cook, 1959
CA	chaparral	D	48	Lawrence, 1966
CA	chaparral	D	48	Wirtz et al., 1988*
P. gossypinus				
AL	longleaf pine	I	18°	Boyer, 1964
FL	slash & longleaf	I	36^{a}	Layne, 1974
LA	loblolly-shortleaf	I	~11	Shadowen, 1963*
LA	loblolly-shortleaf	I	plots varied	Hatchell, 1964
P. leucopus				
IL	tallgrass prairie	I	4	Schramm & Willcutts, 1983
KS	tallgrass prairie	0	24	Kaufman et al., 1983
WI	brush prairie savanna	D	1	Beck & Vogl, 1972
P. maniculatus				
AZ	ponderosa pine	I	~ 8	Lowe et al., 1978
CA	grassland	I	48	Lawrence, 1966
CA	Douglas fir	I^{b}	7	Tevis, 1956a*
CA	grassland	I	30	Cook, 1959
	mixed brush	0	30	"
CA	mixed conifers & hardwoods	I	?	McDonald, 1983*
CA	chaparral	I	48	Wirtz et al., 1988
CO	lodgepole pine	I	3	Roppe & Hein, 1978
ID	mixed conifers	I	1	Stout et al., 1972
ID	sagebrush	I^{c}	4	Halford, 1981
IL	tallgrass prairie	I	4	Schramm & Willcutts, 1983
KS	tallgrass prairie	I	24	Kaufman et al., 1983; Peterson et al., 1985
MN	jack pine	I	36	Ahlgren, 1966*
MN	mixed conifers & hardwoods	ID	144	Krefting & Ahlgren, 1974
MN	jack pine & aspen-fir-spruce	D	2	Buech et al., 1977
MN	prairie	I	36	Tester & Marshall, 1961
MT	larch-Douglas fir	I	~60	Halvorson, 1982*
OH	oat monoculture	D	10	Crowner & Barrett, 1979*
OR	Douglas fir	I	132	Gashwiler, 1970*
OR	Douglas fir	I	21	Hooven & Black, 1976*
SD	ponderosa pine & pine savanna	I	24	Bock & Bock, 1983
SD	prairie	I	36	Forde et al., 1984
WA	conifer forest	D	3	Gunther et al., 1983*
WI	brush prairie savanna	I	1	Beck & Vogl, 1972
WY	sagebrush	I	36	McGee, 1982
BRITISH COLUMBIA				
	mixed conifer	I	2	Garman & Orr-Ewing, 1949*
	mixed conifer	I	8	Sullivan, 1980*
MANITOBA				
	jack pine	I	36	Sims & Buckner, 1973*
ONTARIO				
	black spruce & mixed wood	I	~ 36	Martell, 1984*
P. polionotus				
AL	longleaf pine	I	18	Boyer, 1964
FL	longleaf/turkey oak	0	15	Arata, 1959
GA	old field	I	6	Odum et al., 1973*

TABLE 1. CONTINUED

P. truei				
CA	mixed brush	D	30	Cook, 1959
CA	chaparral	D	48	Lawrence, 1966
"*Peromyscus* spp."				
MN	oak/savanna (tallgrass)	I	2	Tester, 1965
PA	mixed oak	D[c]	15	Fala, 1975[e]
Podomys floridanus				
FL	longleaf/turkey oak	0	15	Arata, 1959
FL	longleaf/turkey oak	0	varied	Jones, 1990

[a] 12 years later there was no significant difference in numbers on burned and unburned sites.
[b] Numbers were lower on uncut areas.
[c] Numbers increased after burn; there were, however, more animals on the control sites.
[d] Then decreased after 7 years.
[e] Numbers higher on the burn (a nonregenerating clearcut) than on control in May and August 1973; higher on the control in May and August 1974.

Forde et al., 1984). G. A. Kaufman and co-workers (1988) pointed out that fire frequency might affect availability of seeds in grasslands. Evidence of quantitative differences in diets was reported in four studies. Tevis (1956*a*) reported that deer mice ate more insects on recent burns and more seeds on older burns; however, McGee (1982) reported that deer mice on unburned sites ate fewer seeds and slightly more insects than on burned areas. Halford (1981) showed that *P. maniculatus* on burns consumed fewer Lepidoptera and more Coleoptera and plant material than mice on unburned sites. Gunther and co-workers (1983) stated that *P. maniculatus* preferred invertebrates in coniferous forests and conifer seeds in clearcuts during summer months; the stomach of the single individual trapped in a burned clearcut contained invertebrates only.

Other biologists related fluctuations of peromyscine populations to changes in litter cover and depth, the number of shelters provided by logs, and other structural qualities of the environment (Tester and Marshall, 1961; Tester, 1965; Beck and Vogl, 1972; Lowe et al., 1978; Blankenship, 1982; Schramm and Willcutts, 1983; G. A. Kaufman et al., 1988; Clark et al., 1989; Clark and Kaufman, 1990). The frequency with which *P. maniculatus* numbers increase after burns (Table 1) is consistent with studies of microhabitat use, in which *P. maniculatus* was found on relatively open ground lacking dense, shrubby growth (e.g., McCabe and Blanchard, 1950; Price and Waser, 1984; Parren and Capen, 1985). Baker (1968) summarized the use of early and late seral stages by *Peromyscus*.

Interspecific competition also might be a factor contributing to the success of deer mice *(P. maniculatus)* in some communities. Deer mouse populations were negatively affected by competition with red-backed voles *(Clethrionomys gapperi)* in larch-fir forests, but deer mice gained a competitive advantage in open situations (e.g., burns) and in years when conifers produced large seed crops (Halvorson, 1982). Schramm and Willcutts (1983) suggested competition between *P. leucopus* and *P. maniculatus*. Vacanti and Geluso (1985) suggested that increases in white-footed mice *(P. leucopus)* and deer mice *(P. maniculatus)* in a burned prairie might be due to both the change in habitat and the removal of voles *(Microtus pennsylvanicus)*.

Effects of fires on parasite load have not been thoroughly studied. Martell (1984) reported that *P. maniculatus* had significantly fewer botfly larvae on burns than on clearcuts ($p < 0.05$). Komarek (1939) also suggested lighter parasite loads on burns, but did not provide specific data. Boggs and co-workers (1991) examined botfly infestations on moderately grazed areas burned and treated with herbicides in Oklahoma; they reported that infestations were significantly higher in populations of *P. leucopus* on burned areas during one year of the three-year study.

Layne (1974) and Martell (1984) both suggested that burned areas might act as "dispersal sinks." Tevis (1956*b*), Cook (1959), Hatchell (1964), Ahlgren (1966), Sims and Buckner (1973), Krefting and Ahlgren (1974), and Vacanti and Geluso (1985) documented dispersal of *Peromyscus* onto burned areas. D. W. Kaufman and co-workers (1988) suggested that odors from burned areas might stimulate immigration of *P. maniculatus* from suboptimal habitats.

Effects of fire on Podomys—The effects of prescribed fires on Florida mice *(Podomys floridanus)* were examined by Arata (1959), Jones (1990), and Layne (1990). *Podomys* primarily is associated with xeric high pine and scrub habitats, both of which are considered pyrogenic (Gates and Tanner, 1988; Jones, 1990; Layne, 1990). Arata (1959) amassed 150 trapnights on traplines prior to a prescribed burn and 1800 trapnights beginning within two weeks after the burn. Trapping success for *Podomys* was 3% and 9% before and after the burn, respectively, and the difference was attributed to animals moving onto the site from surrounding, unburned areas. Arata (1959:101) concluded that the burn had no effect on the local population. Layne's (1990) study sites include long-term monitoring of *Podomys* in sand pine scrub in Levy County and sandhill in Alachua County. He noted that the sand pine scrub area was heavily burned in 1955 and that Florida mice were still present as of 1986, although absolute density and relative abundance of *Podomys* had declined approximately 10 years after the fire.

Jones (1990) trapped at the mouth of gopher tortoise *(Gopherus polyphemus)* burrows inhabited by Florida mice on three different sites (longleaf pine-turkey oak sandhills on three-year rotations of prescribed burns). One study site was trapped for nine months (416 trapnights pre-burn and 676 trapnights post-burn); a second site was trapped for five months (318 trapnights pre-burn and 174 trapnights post-burn); and a third site was trapped for 4.5 years (including 558 trapnights pre- and 805 trapnights post-burn during the year of the prescribed burn). Although trapping methods differed, Jones' (1990) results were similar to those of Arata (1959) in that no immediate effect of fires on *Podomys* was detected. Apparent densities of *Podomys* fluctuated monthly on all three sandhills. However, numbers of mice appeared more constant at burned sites than unburned sites. Trapping success was higher on burned areas and significantly more individuals were captured on burned sites than at unburned burrows (G=10.597, significant at $p<0.005$). Prescribed burns appeared to have little or no immediate effects (i.e., three months immediately following the fire) on these populations. Some populations decreased, but two or three months later numbers equalled or exceeded pre-fire levels. On one sandhill 87% of the 15 animals captured the month prior to the fire were still present during the month after the fire; on the other two sites there was no dispersal or mortality of marked animals (i.e., 100% recovery of marked individuals after burns).

To examine effects of burns on home ranges, Jones (1990) measured home ranges of 13 animals, each of which was captured at least five times. Only one of these individuals moved from burned to unburned burrows after the fire. There was no significant change in home range size for these 13 mice. In the absence of detailed dietary information for *Podomys*, Jones (1990) concluded that fires benefit Florida mice in longleaf pine-turkey oak sandhills by maintaining an open canopy and by increasing the diversity of herbaceous species. Additionally, in this habitat *Podomys* resided extensively in burrows of gopher tortoises, which rely on open canopy conditions maintained by fire or other disturbance (Cox, Inkley, and Kautz, 1987).

Little or no mortality of *Podomys* was directly attributable to fires in either study, for two possible reasons. Because of the uneven distribution of litter and bare patches of sand, the effects of these fires occurred in a mosaic of varying intensity. These were not catastrophic fires that burn or suffocate rodents, as occasionally are observed in other habitats. Secondly, mice were insulated from the heat of the fire by remaining within tortoise burrows. Although logs, holes in trees, and burned-out root channels are used by *Podomys* as temporary shelters (as reported for *Peromyscus* by Baker, 1974, Wolff and Hurlbutt, 1982, and others), Jones (1990) had no evidence that *Podomys* used long-term nests in logs or other structures above ground. Likewise, Layne (1970, 1990) considered *Podomys* to be exclusively burrow-dwelling.

Summary—A literature search of the Journal of Mammalogy and other zoological journals and forestry publications yielded 38 papers in which the purpose was to examine effects of fire on *Peromyscus* or *Podomys*. In most studies relatively short-term effects were examined. Studies on the Konza Prairie Research Natural Area in eastern Kansas by Kaufman and associates (see Kaufman et al., 1990, and references therein) apparently represent the only ongoing research examining long-term effects of fire on *Peromyscus*; J. N. Layne continues to work with *Podomys* in Alachua County and other sites in Florida.

Within these two genera, responses of seven species to fire in a variety of habitats have been examined. More than half of these studies described positive reponse of *P. maniculatus* to fires in both forests and grasslands. This response is consistent with earlier descriptions of a preference of *P. maniculatus* for relatively open ground. For each of the six remaining species—

P. californicus, *P. gossypinus*, *P. leucopus*, *P. polionotus*, *P. truei*, and *Podomys floridanus*—I located four or fewer reports of fire response. At least two of these species *(P. leucopus and P. floridanus)* appear to have neutral responses, at least in the short term (Jones, 1990; Kaufman et al., 1990).

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LITERATURE CITED

AHLGREN, C. E. 1966. Small mammals and reforestation following prescribed burning.J. Forest. 64:614-618.

ARATA, A. A. 1959. Effects of burning on vegetation and rodent populations in a longleaf pine turkey oak association in north central Florida. Quart. J. Fla. Acad. Sci. 22:94-104.

BAKER, R. H. 1968. Habitats and distribution. Pp. 98-126. *In:* KING, J. A., (ed.), Biology of *Peromyscus* (Rodentia), Amer. Soc. Mammal. 593 pp.

BAKER, W. W. 1974. Longevity of lightning-struck trees and notes on wildlife use. Proc. Ann. Tall Timbers Fire Ecol. Confr., Tallahassee, FL. 13:497-504.

BECK, A. M. AND R. J. VOGL. 1972. The effects of spring burning on rodent populations in a brush prairie savanna. J. Mammal. 53:336-346.

BENDELL, J. F. 1974. Effects of fire on birds and mammals. Pp. 73-138. *In:* KOZLOWSKI, T. T., AND C. E. AHLGREN (eds.), Fire and Ecosystems, Academic Press Orlando FL. 542 pp.

BIGHAM, S. R., J. L. HEPWORTH, AND R. P. MARTIN. 1964. A casualty count of wildlife following a fire. Proc. Oklahoma Acad. Sci. 44:47-50.

BLANKENSHIP, D. J. 1982. Influences of prescribed burning on small mammals in Cuyamaca Rancho State Park, California. P. 587. *In:* Conrad, C. E., and W. C. Oechel (tech. coord.), Proc. Symposium on Dynamics and Management of Mediterranean-type Ecosystems. U.S.D.A. Forest Serv. Gen. Tech. Rep. PSW-58 Washington, D. C. 637 pp.

BOCK, C. E., AND J. H. BOCK. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. J. Range Manage. 31:296-300.

————. 1983. Responses of birds and deer mice to prescribed burning in ponderosa pine. J. Wildl. Manage. 47:836-840.

BOGGS, J. F., R. L. LOCHMILLER, S. T. MCMURRY, D. M. LESLIE, JR., AND D. M. ENGLE. 1991. *Cuterebra* infestations in small-mammal communities as influenced by herbicides and fire. J. Mammal. 72:322-327.

BOYER, W. D. 1964. Longleaf seed losses to animals on burned seedbeds. U.S.D.A. Forest Serv. Res. Note SO-6. 3 pp.

BUECH, R. R., K. SIDERITS, R. E. RADTKE, H. L. SHELDON, AND D. ELSING. 1977. Small mammal populations after a wildfire in northeast Minnesota. U.S.D.A. Forest Serv. Res. Pap. NC-151. 8 pp.

CARLETON, M. D. 1990. Systematics and evolution. Pp. 7-141. *In:* KIRKLAND, G. K., JR., AND J. N. LAYNE (ed.), Advances in the study of *Peromyscus* (Rodentia), Texas Tech Univ. Press. Lubbock, TX. 366 pp.

CHEW, R. M., B. B. BUTTERWORTH, AND R. GRECHMAN. 1959. The effects of fire on the small mammal populations of chaparral. J. Mammal. 40:253.

CLARK, B. K. AND D. W. KAUFMAN. 1990. Short-term responses of small mammals to experimental fire in tallgrass prairie. Canad. J. Zoology. 68:2450-2454.

————, D. W. KAUFMAN, E. J. FINCK, AND G. A. KAUFMAN. 1989. Small mammals in tall-grass prairie: patterns associated with grazing and burning. Prairie Nat. 21:177-184.

Cook, S. F., Jr. 1959. The effects of fire on a population of small rodents. Ecology. 40:102-108.

Cox, J., D. Inkley, and R. Kautz. 1987. Ecology and habitat protection needs of gopher tortoise *(Gopherus polyphemus)* populations found on lands slated for large-scale development in Florida. Florida Game and Fresh Water Fish Comm. Nongame Wildlife Program Tech. Rept. No. 4. Tallahassee, FL. 75 pp.

Crowner, A. W. and G. W. Barrett. 1979. Effects of fire on the small mammal component of an experimental grassland community. J. Mammal. 60:803-813.

Erwin, W. J. and R. H. Stasiak. 1979. Vertebrate mortality during the burning of a reestablished prairie in Nebraska. Amer. Midl. Nat. 101:247-249.

Fala, R. A. 1975. Effects of prescribed burning on small mammal populations in a mixed-oak clearcut. J. Forest. 73:586-587.

Florida Game and Fresh Water Fish Commission. 1987. Official lists of endangered and potentially endangered fauna and flora in Florida. Tallahassee, FL. 19 pp.

Forde, J. D., N. F. Sloan, and D. A. Shown. 1984. Grassland habitat management using prescribed burning in Wind Cave National Park, South Dakota. Prairie Nat. 16:97-110.

Fowells, H. A. and G. H. Schubert. 1951. Recent direct seeding trials in the pine region of California. U.S.D.A. Forest Serv. Res. Note No. 78. Washington, D.C. 9 pp.

Garman, E. H. and A. L. Orr-Ewing. 1949. Direct-seeding experiments in the southern coastal region of British Columbia 1923-1949. British Columbia Forest Serv. Tech. Publication T-31. Vancouver, B.C. 45 pp.

Gashwiler, J. S. 1970. Plant and animal changes on a clearcut in west-central Oregon. Ecology 51:1018-1026.

Gates, C. A. and G. W. Tanner. 1988. Effects of prescribed burning on herbaceous vegetation and pocket gophers *(Geomys pinetis)* in a sandhill community. Florida Scient. 51:129-139.

Gunther, P. M., B. S. Horn, and G. D. Babb. 1983. Small mammal populations and food selection in relation to timber harvest practices in the western Cascade Mountains. Northwest Sci. 57:32-44.

Halford, D. K. 1981. Repopulation and food habits of *Peromyscus maniculatus* on a burned sagebrush desert in southeastern Idaho. Northwest Sci. 55:44-49.

Halvorson, C. H. 1982. Rodent occurrence, habitat disturbance, and seed fall in a larch-fir forest. Ecology. 63:423-433.

Harty, F. M., J. M. Ver Steeg, R. R. Heidorn, and L. Harty. 1991. Direct mortality and reappearance of small mammals in an Illinois grassland after a prescribed burn. Natural Areas Journal. 11:114-118.

Hatchell, G. E. 1964. Small-mammal species and populations in the loblolly-shortleaf pine forest type of Louisiana. U.S.D.A. Forest Serv. Res. Paper SO-10. Washington, D.C. 12 pp.

Hedlund, J. D. and W. H. Rickard. 1981. Wildfire and the short-term response of small mammals inhabiting a sagebrush-bunchgrass community. Murrelet. 62:10-14.

Hooven, E. F. and H. C. Black. 1976. Effects of some clearcutting practices on small-mammal populations in western Oregon. Northwest Sci. 50:189-208.

Horn, E. E. 1938. Some wildlife-forest relationships. Trans. North American Wildl. Conf. 3:376-380.

Jones, C. A. 1990. Microhabitat use by *Podomys floridanus* in the high pine lands of Putnam County, Florida. Ph.D. dissert., Univ. Florida, Gainesville, FL.

Kaufman, D. W., E. J. Finck, and G. A. Kaufman. 1990. Small mammals and grassland fires. Pp. 46-80. *In:* Collins, S. L., and L. L. Wallace (eds.), Fire in North American Tallgrass Prairies, Univ. Oklahoma Press, Norman OK.

———, S. K. Gurtz, and G. A. Kaufman. 1988. Movements of the deer mouse in response to prairie fire. Prairie Nat. 20:225-229.

———, and G. A. Kaufman. 1990. Population biology. Pp. 233-270. *In:* Kirkland, G. L., Jr., and J. N. Layne (eds.), Advances in the study of *Peromyscus* (Rodentia), Texas Tech Univ. Press, Lubbock, TX. 366 pp.

———, G. A. Kaufman, and E. J. Finck. 1983. Effects of fire on rodents in tallgrass prairie of the Flint Hills region of eastern Kansas. Prairie Nat. 15:49-56.

Kaufman, G. A., D. W. Kaufman, and E. J. Finck. 1988. Influence of fire and topography on habitat selection by *Peromyscus maniculatus* and *Reithrodontomys megalotis* in ungrazed tallgrass prairie. J. Mammal. 69:342-352.

Kiltie, R. A. 1989. Wildfire and the evolution of dorsal melanism in fox squirrels, *Sciurus niger*. J. Mammal. 70:726-739.

Koehler, G. M. and M. G. Hornocker. 1977. Fire effects on marten habitat in the Selway-Bitterroot Wilderness. J. Wildl. Manage. 41:500-505.

Komarek, E. F. 1939. A progress report on southeastern mammal studies. J. Mammal. 20:292-299.

Krefting, L. W. and C. E. Ahlgren. 1974.Small mammals and vegetation changes after fire in a mixed conifer-hardwood forest. Ecology. 55:1391-1398.

Landers, J. L. 1987. Prescribed burning for managing wildlife in southeastern pine forests. Proc. 1986 Soc. Amer. Foresters Natl. Convention pp. 151-159.

Lawrence, G. E. 1966. Ecology of vertebrate animals in relation to chaparral fire in the Sierra Nevada foothills. Ecology. 47:278-291.

Layne, J. N. 1970. Climbing behavior of *Peromyscus floridanus* and *Peromyscus gossypinus*. J. Mammal. 51:580-591.

———. 1974. Ecology of small mammals in a flatwoods habitat in north-central Florida, with emphasis on the cotton rat *(Sigmodon hispidus)*. Amer. Mus. Novit. 2544:1-48.

———. 1990. The Florida mouse. Pp. 1-21. *In:* Dodd, C. K., Jr., R. E. Ashton, Jr., R. Franz, and E. Wester (eds.), Burrow associates of the gopher tortoise. Eighth Ann. Mtg. Gopher Tortoise Council, Fl. Museum of Natural History, Univ. Florida, Gainesville, FL. 134 pp.

Lowe, P. O., P. F. Folliott, J. H. Dieterich, and D. R. Patton. 1978.Determining potential wildlife benefits from wildfire in Arizona ponderosa pine forests. U.S.D.A. Forest Serv. Gen. Tech. Rep. RM-52. Washington, D.C. 12 pp.

Lyon, L. J., H. S. Crawford, E. Czuhai, R. L. Fredericksen, R. F. Harlow, L. J. Metz, and H. A. Pearson. 1978. Effects of fire on fauna. U.S.D.A. Forest Serv. Gen. Tech. Rep. WO-6. Washington, D.C. 22 pp.

Martell, A. M. 1984. Changes in small mammal communities after fire in north central Ontario. Can. Field-Nat. 98:223-226.

McCabe, T. T. and B. D. Blanchard. 1950. Three species of Peromyscus. Rood Associates, Publ., Santa Barbara, CA.

McDonald, P. M. 1983.Clearcutting and natural regeneration…management implications for the northern Sierra Nevada. U.S.D.A. Forest Serv. Gen. Tech. Rep. PSW-70. Washington, D. C. 11 pp.

McGee, J. M. 1982. Small mammal populations in an unburned and early fire successional sagebrush community. J. Range Manage. 35:177-180.

Moore, A. W. 1940. Wild animal damage to seed and seedlings on cut-over Douglas fir lands of Oregon and Washington. U.S.D.A. Tech. Bull. No. 706. Washington, D.C. 28 pp.

Odum, E. P., S. E. Pomeroy, J. C. Dickinson, III, and K. Hutcheson. 1973.The effects of late winter litter burn on the composition, productivity, and diversity of a 4-year old fallow-field in Georgia. Proc. Ann. Tall Timbers Fire Ecol. Confr., Tallahassee, FL. 13:399-427.

Parren, S. G., and D. E. Capen. 1985. Local distribution and coexistence of two species of *Peromyscus* in Vermont. J. Mammal. 66:36-44.

Peek, J. M. 1986. A review of wildlife management. Prentice-Hall, Englewood Cliffs, NJ. 486 pp.

Peterson, S. K., G. A. Kaufman, and D. W. Kaufman. 1985. Habitat selection by small mammals of the tall-grass prairie: experimental patch choice. Prairie Nat. 17:65-70.

Price, M. V. and N. M. Waser. 1984. On the relative abundance of species: postfire changes in a coastal sage scrub rodent community. Ecology 65:1161-1169.

Rice, L. A. 1932. The effect of fire on the prairie animal communities. Ecology 13:392-401.

Roppe, J. A. and D. Hein. 1978. Effects of fire on wildlife in a lodgepole pine forest. Southwest. Nat. 23:279-288.

Schramm, P. and B. J. Willcutts. 1983. Habitat selection of small mammals in burned and unburned tallgrass prairie. Proc. North American Prairie Conf. 8:49-55.

Shadowen, H. E. 1963. A live-trap study of small mammals in Louisiana. J. Mammal. 44:103-108.

Sims, H. P. and C. H. Buckner. 1973. The effect of clear cutting and burning of Pinus banksiana forests on the populations of small mammals in southeastern Manitoba. Amer. Midland Nat. 90:228-231.

Spencer, D. A. 1955. The effects of rodents on reforestation. Proc. Soc. Amer. Foresters 1955:125-128.

Stickel, L. F. 1968. Home range and travels. Pp. 373-411. *In:* King, J. A. (ed.), Biology of *Peromyscus* (Rodentia), Amer. Soc. Mammal. 593 pp.

STOUT, J., A. L. FARRIS, AND V. L. WRIGHT. 1971. Small mammal populations of an area in northern Idaho severely burned in 1967. Northwest Sci. 45:219-226.

SULLIVAN, T. P. 1980. Comparative demography of *Peromyscus maniculatus* and *Microtus oregoni* populations after logging and burning of coastal forest habitats. Can. J. Zool. 58:2252-2259.

TAYLOR, D. L. 1981. Effects of prescribed fire on small mammals in the southeastern United States. Pp. 109-120. *In:* WOOD, G. W. (ed.), Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Sci. Inst. Clemson Univ., Georgetown, SC. 170 pp.

TERMAN, C. R. 1968. Population dynamics. Pp. 412-450. *In* KING, J. A. (ed.), Biology of *Peromyscus* (Rodentia), Amer. Soc. Mammal. 593 pp.

TESTER, J. R. 1965. Effects of a controlled burn on small mammals in a Minnesota oak-savanna. Amer. Midland Nat. 74:240-243.

——— AND W. H. MARSHALL. 1961. A study of certain plant and animal interrelations on a native prairie in northwestern Minnesota. Minnesota Mus. Nat. History, Occas. Papers 8:viii + 1-51.

TEVIS, L., Jr. 1956*a*. Responses of small mammal populations to logging of Douglas-fir. J. Mammal. 37:189-196.

———. 1956*b*. Effect of a slash burn on forest mice. J. Wildl. Manage. 20:405-409.

U.S.D.A. FOREST SERVICE. 1984. Wildlife and fish habitat management in the Forest Service. Fiscal Year 1982. Washington, D.C. 144 pp.

VACANTI, P. L. AND K. N. GELUSO. 1985. Recolonization of a burned prairie by meadow voles *(Microtus pennsylvanicus).* Prairie Nat. 17:15-22.

VOGL, R. J. 1973. Effects of fire on the plants and animals of a Florida wetland. Amer. Midl. Nat. 89:334-347.

WILLIAMS, O. 1955. Distribution of mice and shrews in a Colorado montane forest. J. Mammal. 36:221-231.

WIRTZ, W. O., D. HOEKMAN, J. R. MUHM, AND S. L. SOUZA. 1988. Postfire rodent succession following prescribed fire in southern California chaparral. Pp. 333-339, *In:* SZARO, P. C., K. E. SEVERSON, AND D. R. PATTON (tech. coord.), Proc. Symp. Mgt. Amphibians, Reptiles, and Small Mammals in North America. U.S.D.A. Forest Serv. Gen. Tech. Rep. RM-166, Ft. Collins, CO, 458 pp.

WOLFF, J. O. AND B. HURLBUTT. 1982. Day refuges of *Peromyscus leucopus* and *Peromyscus maniculatus*. J. Mammal. 63:666-668.

WRIGHT, H. A. AND A. W. BAILEY. 1982. Fire ecology: United States and southern Canada. John Wiley and Sons, New York. 501 pp.

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LEVELS OF ESTRADIOL AND PROGESTERONE IN MALE AND FEMALE *EUCIDARIS TRIBULOIDES* (ECHINODERMATA: ECHINOIDEA) OVER AN ANNUAL GAMETOGENIC CYCLE

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Abstract: *Individuals of the tropical sea urchin* Eucidaris tribuloides *were maintained under ambient photoperiod at 22 °C, 32 ppt and fed* ad libitum *for one year. Samples of testes and ovaries were collected and steroid levels were determined via radioimmunoassay every three months. Progesterone and estradiol were detected at pg concentrations in both testes and ovaries. Levels of estradiol were highest in males and females during the fall when gonads were mature. Levels of progesterone remained high in both males and females over the year. This is the first report of sex steroid levels in any echinoid species during the gametogenic cycle.*

The sex-related steroids, which have regulatory functions in vertebrate reproduction, occur in echinoderms. Estrogenic activity was reported in crude ovarian extracts of the echinoids *Lytechinus variegatus* (Donahue and Jennings, 1937), *Echinometra sp.* (Donahue, 1940) *Arabacia punctulata*, *Strongylocentrotus droebachiensis* (Hagerman et al., 1956), the holothuroid *Stichopus moebius* (Donahue, 1940) and the asteroid *Asterias forbsi* (Hagerman, et al., 1956). More definitive evidence of estradiol and progesterone was demonstrated in ovaries of the asteroid *Pisaster ochraceus* and in the echinoid *Strongylocentrotus franciscanus* (Botticelli et al., 1960, 1961). Radioimmunoassays were used to measure the levels of estrone and progesterone in the asteroid *Asterias rubens* (Dieleman and Schoenmakers, 1979). Echinoderms possess steroid biosynthetic enzymes (Schoenmakers et al., 1977; Walker, 1980) and steroid metabolic pathways (Schoenmakers, 1979; Schoenmakers and Voogt, 1980; Schoenmakers and Voogt, 1981; Hines et al., 1989) similar to those in vertebrates. Levels of sex steroids have been measured during the annual gametogenic cycles of the asteroid *Asterias rubens* (Schoenmakers and Dieleman, 1981; Voogt and Dieleman, 1984), *Sclerasterias mollis* (Xu, 1990; Xu and Barker, 1990a) and *Asterias vulgaris* (Hines et al., 1990a). Seasonal variations in steroid levels in these animals often correlated with changes in germinal cell populations during the annual reproductive cycle, suggesting a hormonal involvement with gametogenesis. No studies have examined the levels or seasonal variations in steroid levels in echinoids.

Eucidaris tribuloides is a subtropical-tropical echinoid with a distribution in the Atlantic from North Carolina (Cerame-Vivas and Gray, 1966) to Brazil (Mortensen, 1928). It is abundant in coral reef habitats (Glynn, 1968) and its intensive grazing habits make it important to these communities (McPherson, 1968b; Lawrence, 1975). *E. tribuloides* has an annual reproductive cycle with different stages of gametogenesis occurring seasonally (McPherson, 1968a). This study reports the presence of sex steroids in testes and ovaries of *E. tribuloides* and relates the levels to the reproductive condition over a reproductive cycle.

MATERIALS AND METHODS—Adult *Eucidaris tribuloides* (mean test diameter ±1 SD=34.6± 3.2 mm, n=50) were collected in shallow waters near Plantation and Tavanier Keys, Florida during June, 1988 and were transported to the laboratory. Individuals were placed into two 40-gallon aquaria equipped with recirculating sea-water filter pumps and aerators. Water temperature and salinity were maintained at 22 °C and 32 ppt. They were fed ad libitum agar blocks made with 5% dry meal (40% protein, 32% carbohydrate, 17% ash, 6% fiber and 5% lipid). No mortality occurred during the experimental period.

Beginning in September 1988, and every three months for nine months following, tissues for steroid determinations were obtained (as described in discussion), pooled for each sex, frozen immediately in liquid nitrogen and stored at –80 °C. Steroid extraction and preparation for radioimmunoassay have been described previously (Hines et al., 1990b). Progesterone and estradiol levels were measured via standard clinical radioimmunoassay kits. Progesterone kits were purchased from Diagnostics Products Corporation, Los Angeles, CA. Estradiol kits were purchased from PANTEX, Santa Monica, CA. Intra- and inter-assay controls of pooled pyloric caeca from *Asterias vulgaris* (contributed by Charles Walker) and CIBA Ligand A, B and C (Corning Diagnostics Corporation, Irvine, CA) were used. Endogenous steroids competed with ^{125}I labeled tracers of high specific activity for either solid-phase (for progesterone) or liquid-phase (for estradiol) highly specific antibodies. Kit-supplied calibrators for progesterone (0-40 ng/ml) and estradiol (0-5120 pg/ml) were used to generate standard curves. Data were transformed to log-logit format and sample and control steroid values were extrapolated from standard curves. Steroid values are presented as pg steroid per gram fresh weight of tissue. Validation data for radioimmunoassays have been obtained by Hines et al., (unpub).

Significant differences among mean gonadal indices were determined by ANOVA. Significant differences among mean gonadal indices on different sampling dates were determined by the Fisher PLSD multiple comparison test. A Student's t test was used to compare differences among mean steroid levels on different sampling dates. The level of significance was determined at $P<0.05$.

RESULTS—Estradiol concentrations ranged from 16-167 and 0-221 pg/g in the ovaries and testes, respectively (Fig. 1). Estradiol levels in the ovaries and testes decreased generally throughout the study period and did not correspond consistently with reproductive status. Highest levels of estradiol occurred in the fall when gonads were mature. Progesterone concentrations ranged from 553-655 and 336-442 pg/g in the ovaries and testes, respectively, (Fig. 2) and remained relatively high throughout the gametogenic cycle. Testicular progesterone levels were lower than ovarian progesterone levels on corresponding dates. Estradiol and progesterone levels in ovaries or testes, respectively, were not significantly different ($P<0.05$) when compared among sampling dates.

DISCUSSION—Sex steroids are present in echinoderms and other marine invertebrates (Burns et al., 1984; Callard et al., 1984; Van Beek and De Loof, 1988; Reis-Henriques and Coimbra, 1990). Levels of sex steroids in testes and ovaries of the asteroids *Asterias rubens* (Schoenmakers and Dieleman, 1981; Voogt and Dieleman, 1984), *Sclerasterias mollis* (Xu, 1990; Xu and Barker, 1990a), and *Asterias vulgaris* (Hines et al., 1990a) change seasonally during

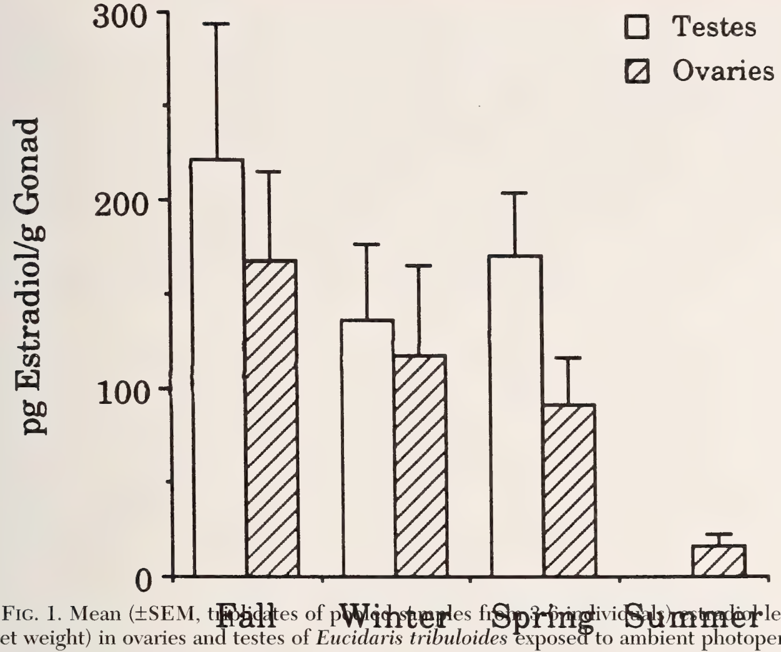

FIG. 1. Mean (±SEM, triplicates of pooled samples from 3-6 individuals) estradiol levels (per g wet weight) in ovaries and testes of *Eucidaris tribuloides* exposed to ambient photoperiod conditions and fed *ad libitum*.

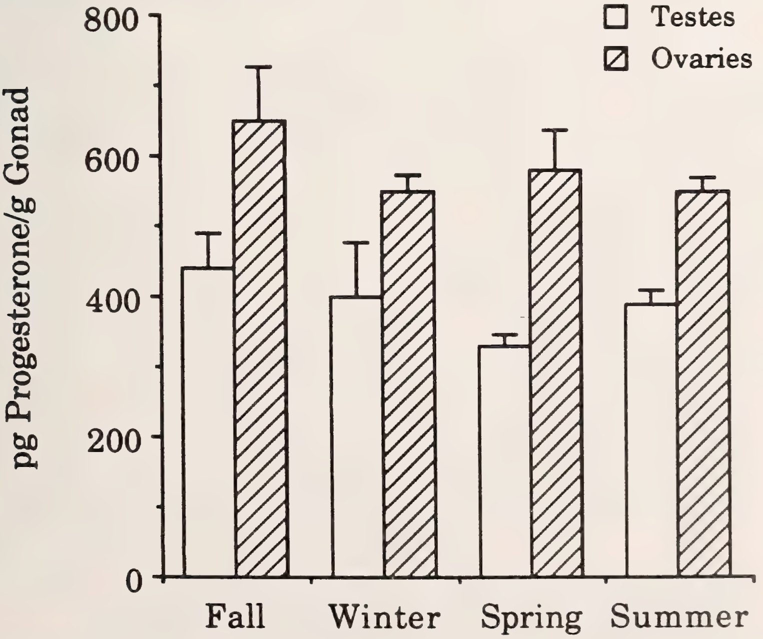

FIG. 2. Mean (±SEM, triplicates of pooled samples from 3-6 individuals) progesterone levels (per g wet weight) in ovaries and testes of *Eucidaris tribuloides* exposed to ambient photoperiod conditions and fed *ad libitum*.

the annual gametogenic cycle. These changes in steroid levels are correlated with changes in germinal cell populations characteristic of either spermatogenesis or oogenesis. *In vitro* (Marsh and Walker, 1990) and *in vivo* (Takahashi, 1982) administration of estradiol to testes of asteroids during the proliferative phase of spermatogenesis increase DNA synthesis and induce spermatogonial mitoses, respectively. In female asteroids and echinoids, estrogens stimulate vitellogenin biosynthesis (Schoenmakers et al., 1981; Takahashi and Kanatani, 1981; Harrington and Ozaki, 1986; Xu and Barker, 1990a) and ovarian growth (Takahashi, 1982; Varaskina and Varaskin, 1988). Sex steroids have important physiological roles in echinoderms (Voogt et al., 1985; Shirai and Walker, 1988).

Steroids (Donahue, 1940; Hagerman et al., 1956) or steroid-like substances (Donahue and Jennings, 1937) have been reported in echinoids. This is the first investigation of steroid levels in an echinoid during the gametogenic cycle. Steroid levels were similar to those reported for other echinoderms during the gametogenic cycle (Schoenmakers and Dieleman, 1981; Voogt and Dieleman, 1984; Xu, 1990; Xu and Barker, 1990a; Hines et al., 1990a). The levels of estradiol and progesterone in *Eucidaris tribuloides* are similar to steroid levels in *Sclerasterias mollis* exposed to experimentally manipulated photoperiods (Xu and Barker, 1990b).

In the field, *Eucidaris tribuloides* has an annual gametogenic cycle, delineated by changes in the reproductive condition of the gonads, with spawning

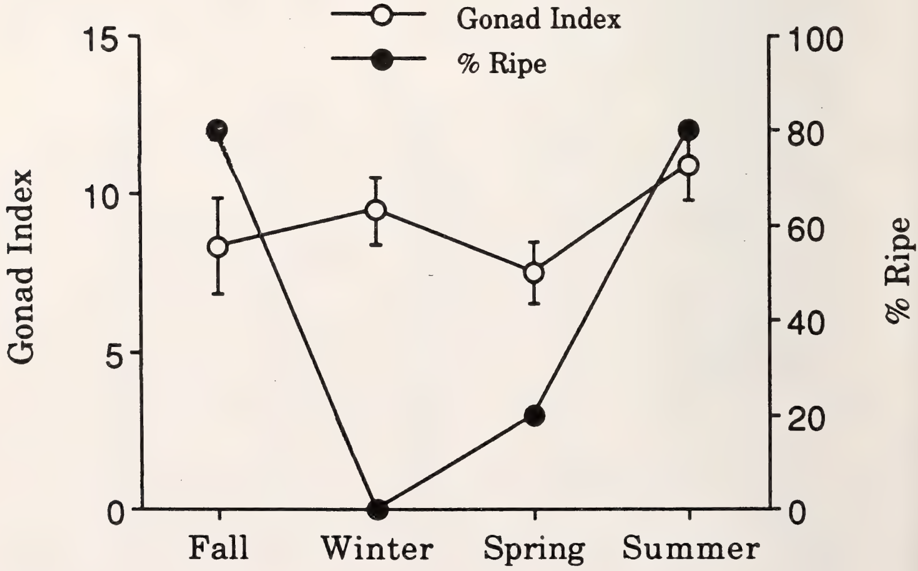

FIG. 3. Gonad cycle of *Eucidaris tribuloides* exposed to ambient photoperiod and fed ad libitum (n=10±SEM); McClintock and Watts, 1990, used with permission.

occurring in the fall (McPherson, 1968a). Under laboratory conditions, *E. tribuloides* exposed to ambient, in-phase photoperiods has a similar pattern of gametogenesis (McClintock and Watts, 1990; Fig. 3, used with permission). Histological evidence of gonads and observations of gonadal indices of *E. tribuloides* exposed to different photoperiodic regimes indicate that gametogenesis may be influenced by photoperiod: shorter daylength (or longer nights) were necessary to initiate gametogenesis (McClintock and Watts, 1990). These data suggest a possible link between the endocrine system, reproductive condition, and the environment.

The steroid levels reported in this investigation demonstrate the presence of sex steroids in gonads of echinoids throughout the gametogenic cycle. However, it is difficult to interpret the physiological significance of changes in steroid levels over three month intervals. Significant changes of gonadal steroid levels in *Asterias vulgaris* occur within one month during specific times of the annual gametogenic cycle (Hines et al., 1990a). Transient changes in steroid levels may have occurred in *Eucidaris tribuloides*, but were not observed. Alternatively, the cellular composition of the gonads of asteroids and echinoids are distinct (Walker, 1982) and may account for differences in endocrine capacity among these classes. Furthermore, experimental conditions may have been sufficient to maintain apparently healthy animals but may not have been sufficient to support normal endocrine functions over the duration of the experiment.

Giese and Pearse (1974) suggested that extrinsic factors such as sea water temperature, salinity, food availability, lunar periodicity and photoperiod may influence the timing of reproductive cycles and/or gametogenic capacity of marine invertebrates, including echinoderms. In addition, Bouland and Jangoux (1988) proposed that while environmental factors initiate gametogenesis in echinoderms, they may not be necessary for the maintenance of gametogenesis. It is unknown how these physical cues elicit physiological responses within an organism. The mechanisms by which extrinsic cues initiate gametogenesis may be mediated via intrinsic cues such as steroid hormones. Patterns of seasonal variation of steroids (in echinoderms) also suggest a role during later stages of the gametogenic cycle, perhaps as initiators of subsequent gametogenic events. An environmentally-stimulated and hormonally-maintained regulation of gametogenesis in some echinoderms seems plausible. Steroids are present in *Eucidaris tribuloides*, and may be important for regulating reproduction, though the influence of environmental factors on steroid levels and the role of steroids in echinoid reproduction remain obscure and require further investigation.

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LITERATURE CITED

BOTTICELLI, C. R., F. J. HISAW, JR., AND H. H. WOTIZ. 1960. Estradiol-17ß and progesterone in ovaries of the starfish *Pisaster ochraceus*. Proc. Soc. Exp. Biol. 103: 875-877.

———., F. J., HISHAW, JR., AND H, H. WOTIZ. 1961. Estrogens and progesterone in the sea urchin (*Strongylocentrotus franciscanus*) and pecten (*Pecten hericius*). Proc. Soc. Exp. Biol. 106: 887-889.

BOULAND, C. AND M. JANGOUX. 1988. Investigation of the gonadal cycle of the asteroid *Asterias rubens* under static conditions. Pp. 169-175. *In*: BURKE, R. D., P. V. MLADENOV, P. LANBERT, AND R. L. PARSLEY. (eds.), Echinoderm Biology. A. A. Balkema, Rotterdam, The Netherlands.

BURNS, B. G ., G. B. SANGALANG, H. C. FREEMAN, AND M. MCMENEMY. 1984. Isolation and identification of testosterone from the serum and testes of the American lobster (*Homarus americanus*). Gen. Comp. Endocrinol. 54: 429-432.

CALLARD, G. V., J. A. PUDNEY, S. L. KENDALL, AND R. REINBOTH. 1984. *In vitro* conversion of androgen to estrogen in amphioxus gonadal tissues. Gen. Comp. Endocrinol. 56: 53-58.

CERAME-VIVAS, M. J. AND I. E. GRAY. 1966. The distributional pattern of benthic invertebrates of the continental shelf off North Carolina. Ecology. 47: 260-270.

DIELEMAN, S. J., AND H. J. N. SCHOENMAKERS. 1979. Radioimmunoassays to determine the presence of progesterone and estrone in the starfish *Asterias rubens*. Gen. Comp. Endocrinol. 39: 534-542.

DONAHUE, K. J. 1940. Occurence of estrogens in the ovaries of certain marine invertebrates. Endocrinology. 27: 149-152.

——— AND D. E. JENNINGS. 1937. The occurrence of estrogenic substances in the ovaries of echinoderms. Endocrinology. 21: 875-877.

GIESE, A. C. AND J. S. PEARSE. 1974. Introduction: general principles. Pp. 1-49. *In*: GIESE, A. C. AND J. S. PEARSE (eds.), Reproduction of Marine Invertebrates. Academic Press, New York.

GLYNN, P. W. 1968. Mass mortalities of echinoids and other reef flat organisms coincident with midday, low water exposures in Puerto Rico. Mar. Biol. 1: 226-243.

HAGERMAN, D. D., F. M. WELLINGTON, AND C. A. VILLEE. 1956. Estrogens in marine invertebrates. Biol. Bull. 112: 180-183.

HARRINGTON, F. E. AND H. OZAKI. 1986. The effect of estrogen on protein synthesis in echinoid coelomocytes. Comp. Biochem. Physiol. 84B:417-421.

HINES, G. A., S. A. WATTS, P. A. VOOGT, AND C. W. WALKER. 1989. Steroid metabolism in gametic and somatic tissues of the sea star *Asterias vulgaris*. Amer. Zool. 29: 435A.

HINES, G. A., S. A. WATTS, S. A. SOWER, AND C. W. WALKER. 1990a. Sex steroid levels in the testes, ovaries and pyloric caeca of the sea star *Asterias vulgaris*. Amer Zool. 30: 13A.

———, S. A. WATTS, S. A. SOWER, AND C. W. WALKER. 1990b. Sex steroid extraction from echinoderm tissues. J. Liq. Chromatog., 13: 2489-2498.

LAWRENCE, J. M. 1975. On the relationship between marine plants and sea urchins. Mar. Biol. Oceanog. Ann. Rev. 13: 578-590.

MARSH, A. G., AND C. W. WALKER. 1990. Interaction of estradiol and progesterone during initiation of spermatogenesis in a starfish. Amer. Zool. 30: 53A.

MCCLINTOCK, J. B. AND S. A. WATTS. 1990. The effects of photoperiod on gametogenesis in the tropical sea urchin *Eucidaris tribuloides* (Lamarck) (Echinodermata: Echinoidea). J. Exp. Mar. Biol. Ecol. 139: 175-184.

MCPHERSON, B. F. 1968a. Contributions to the biology of the sea urchin *Eucidaris tribuloides* . Bull. Mar. Sci. 18: 400-443.

———. 1968b. Feeding and oxygen uptake of the tropical sea urchin *Eucidaris tribuloides*. (Lamarck). Biol. Bull. 135: 308-321.

MORTENSEN, T. 1928. Cidaroides. Pp. 551. *In*: A monograph of the Echinoidea. C. A. Reitzel. Copenhagen.

REIS-HENRIQUES, M. A. AND J. COIMBRA. 1990. Variations in the levels of progesterone in *Mytilus edulis* during the annual reproductive cycle. Comp. Biochem. Physiol. 95A: 343-348.

SCHOENMAKERS, H. J. N. 1979. *In vitro* biosynthesis of steroids from cholesterol by the ovaries and pyloric caeca of the starfish *Asterias rubens*. Comp. Biochem. Physiol. 63B: 179-184.

——— AND S. J. DIELEMAN. 1981. Progesterone and estrone levels in the ovaries, pyloric caeca and perivisceral fluid during the annual reproductive cycle of the starfish *Asterias* *rubens*. Gen. Comp. Endocrinol. 43: 63-70.

——— AND P. A. VOOGT. 1980. *In vitro* biosynthesis of steroids from progesterone by the ovaries and pyloric caeca of the starfish *Asterias rubens*. Gen. Comp. Endocrinol. 41: 408-416.

——— AND P. A. VOOGHT. 1981. *In vitro* biosynthesis of steroids from androstenedione by the ovaries and pyloric caeca of the starfish *Asterias rubens*. Gen. Comp. Endocrinol. 45: 242-248.

———, P. H. J. M. COLENBRANDER, AND J. PEUTE. 1977. Ultrastructural evidence for the existence of steroid synthesizing cells in the ovary of the starfish, *Asterias rubens* (Echinodermata). Cell Tiss. Res. 182: 275-279.

———, C. G. VAN BOHEMEN, AND S. J. DIELEMAN. 1981. Effects of oestradiol-17ß on the ovaries of the starfish *Asterias rubens*. Develop. Growth. Differ. 23(2): 125-135.

SHIRAI, H. AND C. W. WALKER 1988. Chemical control of asexual and sexual reproduction in echinoderms. Pp. 453-476. *In*: (LAUFER, H. AND R. G. H. DOWNER (eds.), Endocrinology of Selected Invertebrate Types. Alan R. Liss Inc., New York.

TAKAHASHI, N. 1982. Effect of injection of steroids on the starfish testis, *Asterina pectinifera*. Bull. Japan. Soc. Sci. Fish. 48: 513-515.

——— AND H. KANATANI. 1981. Effect of 17ß-estradiol on growth of oocytes in cultured ovarian fragments of the starfish, *Asterina pectinifera*. Develop. Growth and Differ. 23: 565-569.

VAN BEEK, E. AND A. DE LOOF. 1988. Radioimmunological determinations of concentrations of six C_{21}, C_{19} and C_{18} steroids during the reproductive cycle of female *Artemia* sp. (Crustacea: Anostraca). Comp. Biochem. Physiol. 89A:595-599.

VARAKSINA, G. S. AND A. A. VARAKSIN. 1988. Effect of estradiol dipropionate on oogenesis of the sea urchin *Strongylocentrotus nudus*. Biologiya Morya, 4: 47-52.

VOOGT, P. A. AND S. J. DIELEMAN. 1984. Progesterone and estrone levels in the gonads and pyloric caeca of the male sea star *Asterias rubens*: a comparison with the corresponding levels in the female sea star. Comp. Biochem. Physiol. 79A: 635-639.

———, J. J. S. BROERTJES, AND R. C. H. M. OUDEJANS. 1985. Vitellogenesis in sea star: physiological and metabolic implications. Comp. Biochem. Physiol. 80A: 141-147.

WALKER, C. W. 1980. Spermatogenic columns, somatic cells, and the microenvironment of germinal cells in the testes of asteroids. J. Morphology. 166: 81-107.

———. 1982. Nutrition of Gametes. Pp. 449-468. *In*: JANGOUX, M. AND J. M. LAWRENCE (eds.). Echinoderm Nutrition. A. A. Balkema, Rotterdam, The Netherlands.

XU, R. A. 1990. Studies on the reproductive biology of the forcipulate starfish *Sclerasterias mollis* (Echinodermata: Asteroidea). Ph.D. dissert. Univ. Otago, New Zealand.

——— AND M. F. BARKER. 1990a. Annual changes in the steroid levels in the ovaries and the pyloric caeca of *Sclerasterias mollis* (Echinodermata: Asteroidea) during the reproductive cycle. Comp. Biochem. Physiol. 95A: 127-133.

——— AND M. F. BARKER. 1990b. Photoperiodic regulation of oogenesis in the starfish *Sclerasterias mollis* (Hutton 1872) (Echinodermata: Asteroidea). J. Exp. Mar. Biol. Ecol. 141: 159-168.

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SEASONALITY AND COMPONENTS OF OAK LITTERFALL IN SOUTHEASTERN FLORIDA

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Abstract: *Litter biomass from biweekly basket collections was measured for seventeen months in two low hammocks in St. Lucie and Indian River Counties. A disturbed roadside habitat with both* Quercus virginiana *(live oak) and the exotic* Grevillea robusta *(silk oak) produced significantly more litter and exhibited higher variance among baskets and collection dates than an undisturbed hammock containing only* Q. virginiana*. Peak litterfall occurred in February at the disturbed site and more than one month later at the protected site 12 km distant. Differences between sites are probably attributable to differing species compositions and the relative importance of disturbance. Peak flowerfall lagged leaf fall by* ca *1.5 months at each site.*

In subtropical, peninsular Florida, low hammocks containing predominantly temperate trees are common features of the vegetative landscape. Low hammocks often consist of tree islands in which *Quercus virginiana* Mill. and *Sabal palmetto* (Walt.) Lodd. ex Schultes are the dominant arboreal species (Richardson, 1977). Although the evergreen nature of *Q. virginiana* underlies its common name of live oak, leaf dehiscence and new growth occur seasonally. The phenology of flowering, leaf sprout and fall has been described for *Q. virginiana* in Texas (Frankie et al., 1979) and temperate north Florida (Connor, 1989), but not in subtropical peninsular Florida. No estimates of annual litter production in subtropical low hammocks are available, in spite of the importance of oak litter to detritus-based food chains. For example, litterfall captured in rot cavities of trees provides the resource base for the aquatic insect community, primarily mosquito larvae, that inhabits water-containing treeholes (Fish and Carpenter, 1982; Walker and Merritt, 1988); in south Florida, such treeholes are found predominantly in oak. In order to evaluate the role of oak litter as a resource for treehole mosquitoes, we examined litterfall in two hammocks previously known to us for their production of treehole mosquitoes (Lounibos, 1983). These two hammocks differ in physical characteristics and are not necessarily typical of this ecosystem in southern Florida.

Study Areas—A relatively undisturbed low hammock on the grounds of the University of Florida's Florida Medical Entomology Laboratory (FMEL) (27.6°N, 80.5°W) near Vero Beach in southern Indian River County provided one study site. In this 4-ha hammock lying 1.5 km west of the Intracoastal Waterway (Indian River), *Q. virginiana* and, to a lesser extent, *S. palmetto* are the dominant trees. Ambient temperatures were recorded in this hammock continuously throughout the study. Daily rainfall was measured at a station 6.5 km NW of FMEL.

The second site (Indrio) consisted of two rows of old oak trees bisected by Indrio Road in northern St. Lucie County (27.5° N, 80.5° W). This comparatively disturbed site was composed of live and silk oak (*Grevillea robusta* A. Cunn.), the latter an Australian species of Proteaceae, probably now naturalized in south Florida (Long and Lakela, 1971).

METHODS—At each site we selected five oaks known to harbor water-containing treeholes. For collecting litter, plastic plant pots, 26.2 cm in diameter and 25.4 cm deep, were suspended, one per tree, 2 m above ground from selected trees. The baskets were lined with plastic screen (0.76 mm mesh) which was removed and replaced fortnightly from February 1986 through June 1987. Samples were separated with the aid of a dissecting microscope into seven classes: leaves, twigs, bark, seeds and fruits, flowers, invertebrates and other; the last class included all detritus that could not be assigned to any of the former categories. No attempt was made to classify litter by tree species. After sorting, litter components were dried at 80°C for 48 h before weighing to the nearest 0.01 g. Data were converted to g/m^2 for analyses and presentation.

RESULTS—January and February were the coldest and most variable months in temperature during the study (Fig.1A), conforming with the average annual pattern in the Florida peninsula (Chen and Gerber, 1990). During the study period rainfall did not appreciably increase in the summer, usually the period of maximum precipitation (Jordan, 1984), but 428 mm fell in October 1986, an unusually large amount. The October rains were sometimes accompanied by high winds. A total of 1413 mm of rain was recorded between February 1986-87, more than the average annual range of 1219-1320 mm for the years 1951-80 in Indian River and St. Lucie Counties (Jordan, 1984).

At FMEL, total litter biomass peaked in late March of both 1986 and 1987 (Fig.2A) with the lowest accumulations from June through September. A secondary peak in biomass occurred in late September. At Indrio, the early annual maxima of litter biomass occurred *ca* 1.5 months earlier than at FMEL in both years (Fig.2B). An autumnal peak was also present at Indrio, but it occurred slightly later than at FMEL.

Flowerfall was highly seasonal and also desynchronized between sites (Fig.3). Peaks in flower biomass occurred in late February at Indrio and mid-April at FMEL and accounted for 2-2.5X as much mass at the former site.

The total litter accumulations during one year were analyzed as a two-way ANOVA without replication with sites and litter components as independent variables. Differences between sites and among components were both significant (Table 1). Although leaves accounted for a greater proportion of total biomass at FMEL (70.3%) than at Indrio (49.3%), and seeds and fruits were more common at the latter site, the rank order of importance of the components was similar between localities. This concordance was confirmed by the small interaction (=remainder) sums of squares in ANOVA (Table 1).

Variance in biomass collections was examined among baskets at each site by one-way ANOVAs on all seventeen months of data. F_{max} tests revealed significant heteroscedasticity among baskets at FMEL ($F_{5,35}=5.7$, $P<0.01$) and Indrio ($F_{5,35}=238.4$, $P<<0.01$). A $\log_{10}$ transformation satisfactorily homoge-

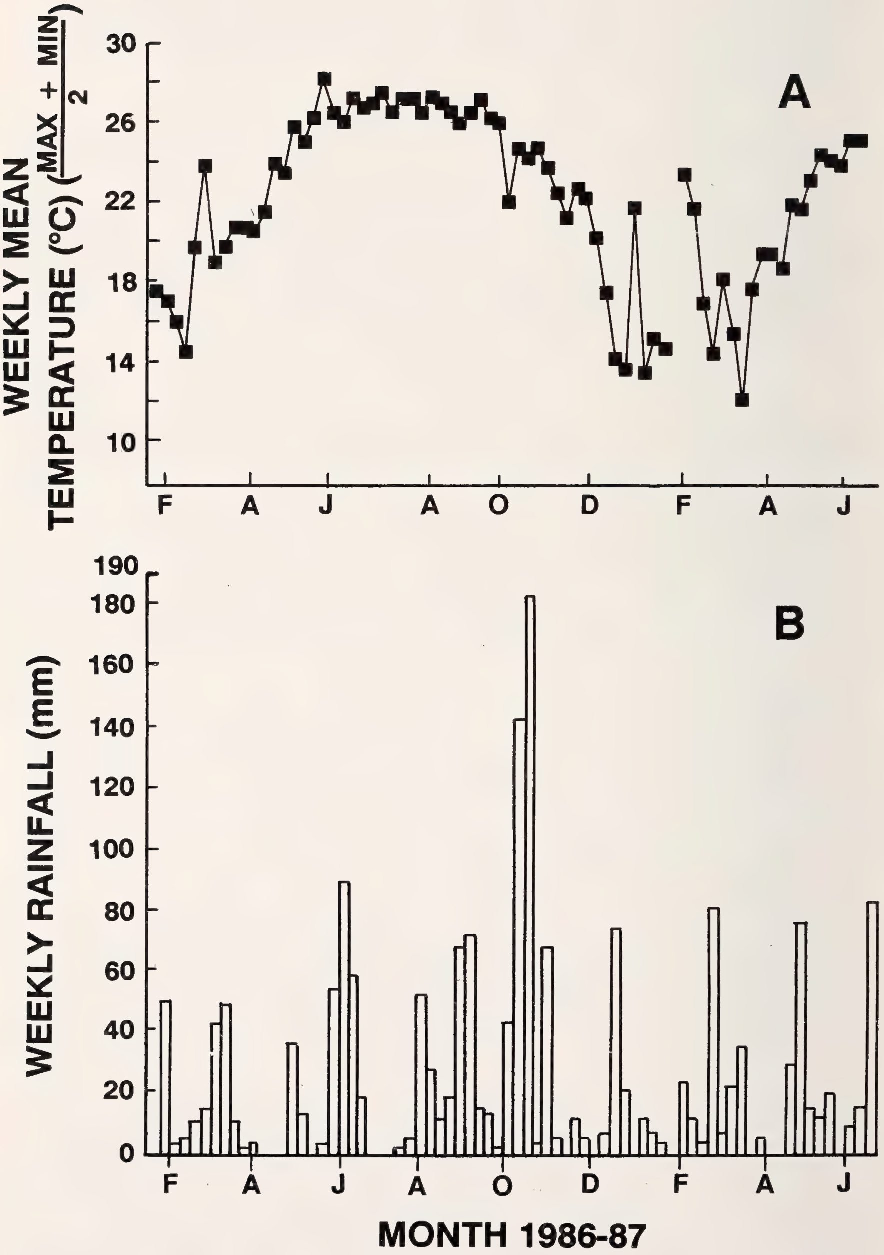

FIG. 1. (A) Weekly mean temperatures during the study period at FMEL. No data were available for the second week of February, 1987. (B) Weekly rainfall during the study period at a station 6.5 km NW of Vero Beach.

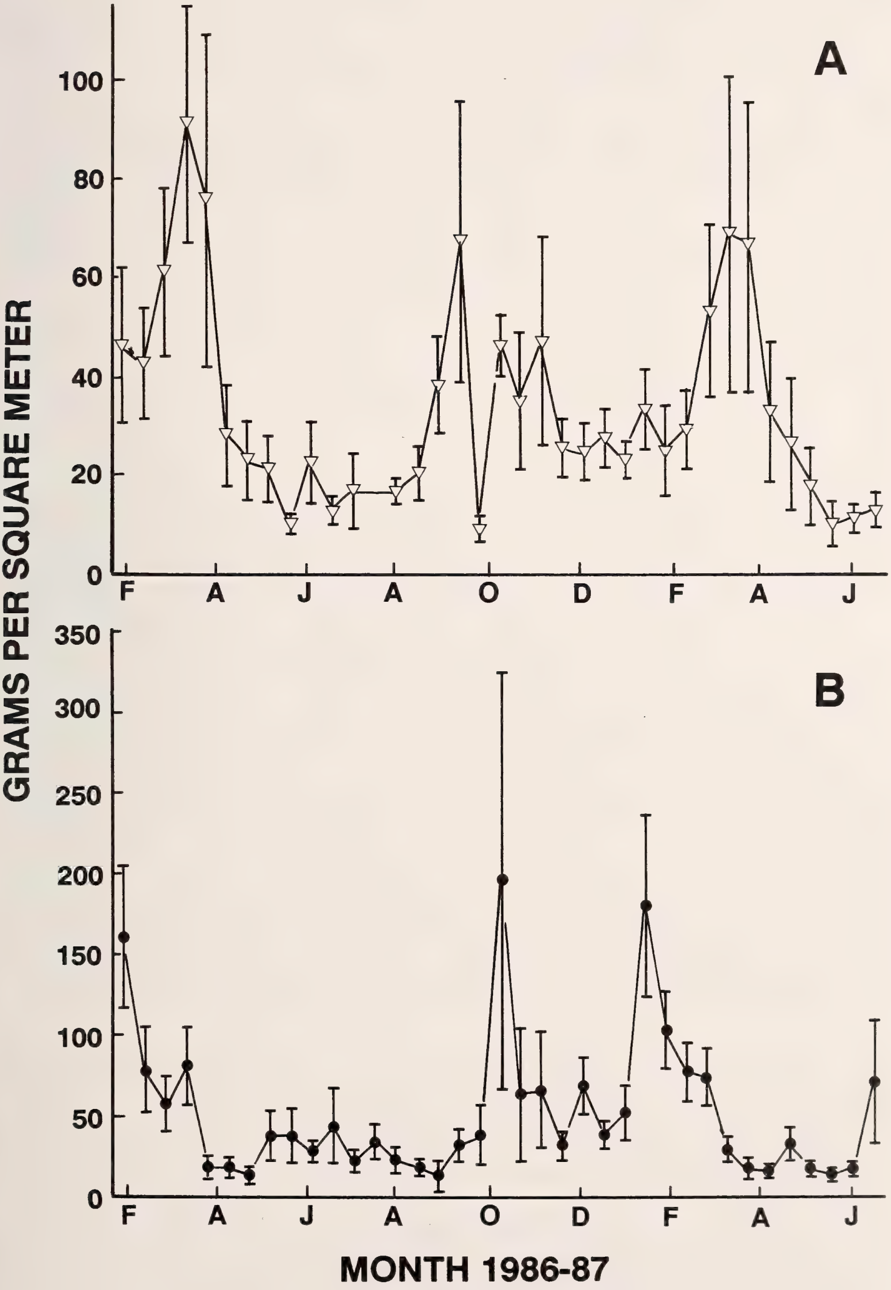

FIG. 2. Seasonal litterfall accumulated fortnightly beneath oaks at (A) FMEL and (B) Indrio. No data were available for the second fortnight of July, 1986. Means and standard errors are from five baskets per sample date, each measure converted to a per m^2 basis.

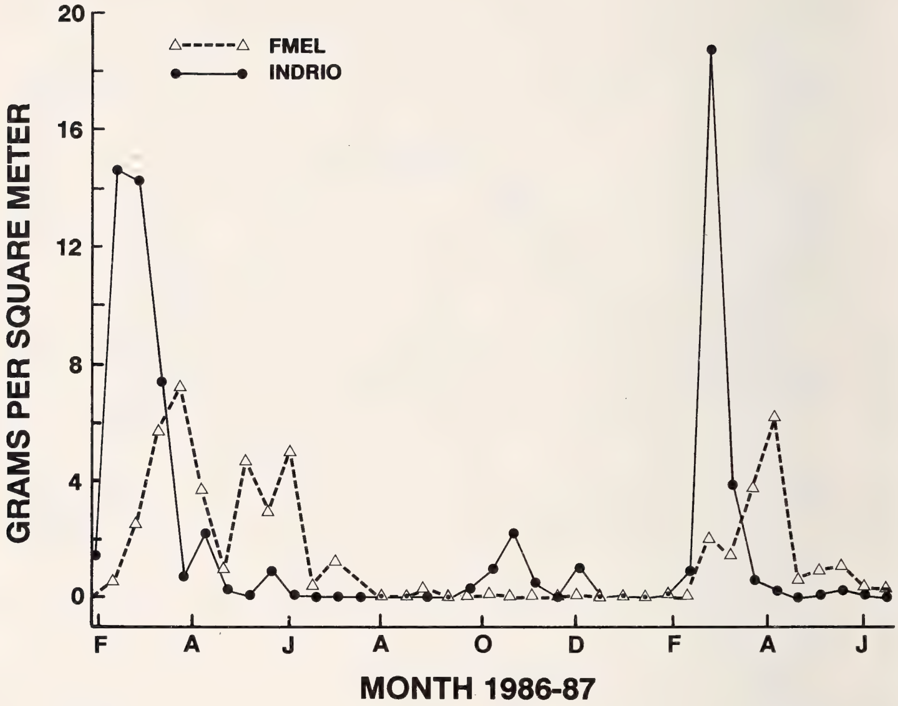

FIG. 3. The biomasses (means of five basket samples) of flowers in seasonal litter samples at FMEL and Indrio.

nized variances, and ANOVA of transformed data revealed significant differences among baskets at FMEL ($F_{4,174}$=4.6, P=0.002) and Indrio ($F_{4,171}$=34.3, P <0.001).

Variances between sites were compared by selecting (from non-transformed data) the median values of basket variances and performing an F_{max} test. The variance ratio of Indrio/FMEL medians was 3.4, indicating significant heteroscedasticity ($F_{.01(2,30)}$=2.6) and greater variability at the more disturbed site.

DISCUSSION—March is the primary month for leaf drop of *Q. virginiana* in Austin, Texas (Frankie et al., 1979) and Tallahassee, Florida (Connor, 1989), localities *ca* 2.5 degrees in latitude north of our study sites. The coincidence of peak litterfall timing in central Texas, north Florida and FMEL (Fig.2A) suggests that the milder, subtropical temperatures of our site do not advance the seasonal chronology of leaf fall. Frankie and co-workers (1979) also noted that flowering in Texan *Q. virginiana* begins just after leaf drop, which concurs with the measured lag between leaf and flower fall in south Florida (cf. Figs. 2, 3).

Litterfall maxima in the autumn may be the result of a combination of factors, among these acorn drop, known to occur approximately six months after

TABLE 1. Annual abundance of the components of litter at two sites and two-way analysis of variance.

Site	COMPONENTS (g/m^2 accumulated February 1986-87)						
	leaves	twigs	bark	seeds and fruit	flower	invert.	other
FMEL	628.0	115.5	44.4	25.3	36.0	7.3	37.0
% total	70.3	12.9	5.0	2.8	4.0	0.8	4.1
INDRIO	703.5	205.2	154.8	236.1	47.1	2.4	70.1
%total	49.6	14.5	10.9	16.6	3.3	0.2	4.9

ANOVA

Source	df	SS	MS	F
site	1	19,740	19,740	7.37^{*}
components	6	619,069	103,178	38.5^{***}
remainder	6	16,067	2,678	

*=$P<0.05$, ***=$P<0.001$

flowering in *Q. virginiana* (Frankie et al., 1979), and storms during October, 1986. Acorn drop is more likely to have been important at FMEL, where the litter peak appeared before October (Fig. 2A). By contrast at Indrio, litterfall and heavy rains were temporally coincident (Figs. 1B, 2B), suggesting a causal relationship.

Desynchronization of litterfall between nearby sites can be influenced by hydrology (e.g., Martinez-Yrizar and Sarukhan, 1990), but hydrological differences between Indrio and FMEL are not known. The presence of *G. robusta* at Indrio probably contributes to certain differences between this site and FMEL. The silk oak has showy, tomentose flowers, copious seeds, and lighter leaves than live oak, which would account for the greater relative contribution at Indrio of reproductive structures among biomass components (Table 1). Thus, differences in tree species composition may account for some of the site differences identified in our study.

FMEL was very similar in litter components to several tropical deciduous forests where leaves accounted for 69-73%, wood 17%, and reproductive structures 6-9% of total annual biomass (Martinez-Yrizar and Sarukhan, 1990). On a latitudinal gradient of deciduous forests, the biomass of annual litterfall increases with decreasing latitude (Jordan and Murphy, 1978). The annual productivity of 700-1,000 g/m^2 at our subtropical sites fits intermediately into the temperate-tropical continuum, these values being more than the annual productivity of most temperate forests, but less than the average tropical forest (Leigh and Windsor, 1982).

The greater variance among basket collections at Indrio may be related to human disturbances at this site where traffic, including large trucks, passes close to trees. High variances among collection dates, as well as significant variation in biomass accumulation among baskets, may underlie the temporal and spatial patchiness of productivity in the insect communities which depend on litterfall detritus.

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LITERATURE CITED

Chen, E. and J. F. Gerber. 1990. Climate. Pp. 11-34. *In*: Myers, R.L. and J.J. Ewel, (eds.), Ecosystems of Florida. Univ. Central Florida Press, Orlando. 765 pp.

Connor, E.F. 1989. Dept. of Environmental Sciences, Univ. Virginia, Charlottesville, VA pers. comm.

Fish, D. and S. R. Carpenter. 1982. Leaf litter and larval mosquito dynamics in tree-hole ecosystems. Ecology 63:283-288.

Frankie, G. W., J. M. Tucker, and J. B. Welch. 1979. Arthropod fauna of live oak in urban and natural stands in Texas. I. Site descriptions, oak taxonomy/phenology and sampling methods. J. Kans. Ent. Soc. 52:71-85.

Jordan, C. L. 1984. Florida's weather and climate: implications for water. Pp. 18-35. *In:* Fernald, E.A. and D.J. Patton (eds.) Water Resources Atlas of Florida. Florida State Univ. Press, Tallahassee, FL. 291 pp.

Jordan, C. F. and P. G. Murphy. 1978. A latitudinal gradient of wood and litter production and its implication regarding competition and species diversity in trees. Amer. Midl. Nat. 99:415-434.

Leigh, E. G., Jr. and D. M. Windsor. 1982. Forest production and regulation of primary consumers on Barro Colorado Island. Pp. 111-122. *In:* Leigh, E. G., Jr., A. S. Rand and D. M. Windsor, (eds.) The Ecology of a Tropical Forest. Smithsonian Press, Washington, D.C. 468 pp.

Long, R. W. and O. Lakela. 1971. A Flora of Tropical Florida. Univ. Miami Press. Coral Gables. 962 pp.

Lounibos, L. P. 1983. The mosquito community of treeholes in subtropical Florida. Pp. 223-246. *In:* Frank, J. H. and L. P. Lounibos, (eds.) Phytotelmata: Terrestrial Plants as Hosts for Aquatic Insect Communities. Plexus Publ. Medford, NJ. 293 pp.

Martinez-Yrizar, A. and J. Sarukhan. 1990. Litterfall patterns in a tropical deciduous forest in Mexico over a five-year period. J. Trop. Ecol. 6:433-444.

Richardson, D. R. 1977. Vegetation of the Atlantic Coastal Ridge of Palm Beach County, Florida. Florida Scient. 40:281-330.

Walker, E. D., and R. W. Merritt. 1988. The significance of leaf detritus to mosquito (Diptera: Culicidae) productivity from treeholes. Envir. Ent. 17:199-206.

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STATUS OF *STYLISMA ABDITA* (CONVOLVULACEAE) IN SOUTHWESTERN FLORIDA—*Daniel F. Austin*(1) *and James N. Burch*.(2)

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Abstract: Stylisma abdita *is a rare endemic confined to sandhill and scrub habitats in the Florida peninsula. In much of its range the species is endangered by urbanization. Exact localities are given for the species in the southwestern Florida counties of Collier and Lee, from which areas the species will soon be extirpated. Phenology and species associates are also discussed.*

Apparently little has been added to the knowledge of *Stylisma abdita* Myint since it was first described (Myint, 1966). The only other times it has been mentioned in the literature were by Long (1970), who transferred the species to *Bonamia*, by Long and Lakela (1971) in their flora, and in checklists (Kartesz and Kartesz, 1980; U.S.D.A., 1982; DeLaney et al., 1989; DeLaney and Wunderlin, 1989). Wunderlin (1982b) made a status survey of the species for the U.S. Fish & Wildlife Service which gives associated species and specimen citations, but that document has not been published. Even fewer data are given by Cristman (1988) who only mentioned the species in scrub, and Muller (1990) does not include the taxon. Because of this lack of knowledge, the first author asked the second to examine the plants in the field. This monitoring has now been going on for the past five years. Because it is becoming increasingly obvious that the known Collier Co. populations of this Florida endemic will soon disappear due to urbanization, it seems timely to provide more information on the status and distribution of the species.

Myint (1966) listed the species from Clay, Collier, Highlands, Marion, Polk and Putnam Counties. Wunderlin (1982b) added Citrus County to the list of known sites and included specimens collected more recently than those cited by Myint (1966). Among these counties, the only sites where the species was formerly reported that remain protected are in Avon Park (Highlands Co.), Gold Head Branch State Park (Clay Co.), and Ocala National Park (Marion Co.). The status of the populations in all counties but Collier is rare (Wunderlin, 1982a,1982b; pers. comm. 1991), but the species is constantly associated with the endangered habitats of scrub or sandhill.

Myint (1966) did not comment on the frequency of the species in the state, although the small number of collections cited in the protologue of the species may suggest that he knew it from few sites. Wunderlin (1982a) listed the species as rare in the central counties. All of the current data indicate that the species is perhaps stable in some of the northernmost counties, but rapidly declining in Collier and Lee counties. We wish to draw the attention of interested parties to this species, suggest that it be included on the state list of endangered and threatened species, and provide additional data on the southwestern populations. Since no exact locality details were given by Myint (1966) on where the species was found in Naples, the following data provide more exact data with legal descriptions of the sections. This is the first record for the species in Lee county and we include the first published record for Citrus County based on the report by Wunderlin (1982b) and the specimens at USF.

Myint found the species to flower from "...early May to late July..." Plants are now known to flower from April into late November (rarely December). Fruits are present on specimens from September, October and December.

Stylisma abdita has been found in Lee and Collier Counties only in xeric scrub systems on St. Lucie fine sand (Leighty et al., 1954) extending south to Marco Island. The species is most often found in open, unshaded areas dominated by rosemary (*Ceratiola ericoides* Michx.) or sand live oak (*Quercus geminata* Small). Associated ground cover is usually sparse and consists of little more than lichens or spikemoss (*Selaginella arenicola* Underw.). This *Stylisma*, like the others, never forms dense populations, but in some small areas it is a common part of the flora. Occasionally the species may be found in shaded areas beneath oaks (*Quercus* spp.) or slash pines (*Pinus elliottii* Engelm.); in these situations the leaves are generally lighter colored and larger, and the stem internodes longer. Plants seldom occur in dense shade or in crowded areas. Stems and leaves are often nearly hidden beneath leaf litter or sand. Farther north in the state the species is not only associated with scrub, but also with sandhill . Other associated species are listed by Wunderlin (1982b), Delaney and co-workers (1989), and Delaney and Wunderlin (1989).

Stylisma abdita appears to be a perennial herb. One to several stems grow radially from a single, deeply extended taproot, and grow mostly during the summer; some or all stems may senesce and die during the dry winter season. Taproots are narrowly conical, reach nearly 1.0 cm in diameter, and terminate flatly near the substrate surface. Lateral stems radiate from the flat basipetal end of the taproot, and may branch several times. Stems are usually 1-3 dm long, but may reach nearly one meter. Stems are prostrate and lie beneath, on, or just above the substrate surface. Leaves are distichous and parallel to the ground surface. Lateral growth of stems beneath the ground surface is common and often extensive. These extensions occur parallel to and about 1 cm beneath the ground surface. Underground stems are pale, leafless and often branched. No adventitious roots or cleistogamous flowers have been noted on subterranean stems.

Xeric scrub habitats are uncommon in southwestern Florida. Those scrub habitats remaining in Collier County are the southernmost in North America. Landsat satellite information from the Florida Game and Freshwater Fish Commission indicates that about 0.040% (ca. 221 ha) of Collier County's area is presently occupied by xeric scrub communities (Florida Game and Freshwater Fish Commission, 1989).

As high, dry areas, scrub ridges have historically been among the first compromised by human settlement. Early transportation routes (e.g.

Tamiami Trail, Atlantic Coastal R.R.) were constructed on these ridges, and adjacent areas subsequently settled. Many of these areas continue to be prime residential and commercial development properties. Almost all known scrub habitats in Collier County are now zoned either Residential or Commercial, and are located within the "Urban Designated Areas" of the County (Collier County Board of County Commissioners, 1989).

Development pressure on these habitat areas is exacerbated by the fact that they are usually the last choice for preserve areas within developments. Projects may be required, through development orders, to preserve certain areas, but these usually serve more than one function (e.g., wetlands are often used in water management designs; preservation of wetlands may be required through Florida Statute 373.414). The presence of animal species listed for protection (see Wood, 1990) may provide regulatory agencies with sufficient authority to require habitat preservation, if no other solution to protection of these animals is found (Florida Statute 372.072,The Endangered and Threatened Species Act).

Protection of upland floras, however, is not well established by State legislation. Many plant species are listed with some status of threat to their populations (Wood, 1990), but this offers little or no actual protection. At the local government level, however, more stringent habitat preservation requirements may be enacted (Florida Statute 163.3202,Florida Administrative Code, Ch. 9J-5). Local regulations may be similar to State or Federal rules, but provide more specific requirements based on data and analysis of the immediate area. Decisions must be made at this level to establish priorities and criteria for habitat protection in each jurisdiction (Katzman and Kale, 1990). Therefore, the condition of one or more resident species is valuable information for county or municipal governments, and may be useful in making site specific determinations for habitat management.

SPECIMENS EXAMINED—Citrus Co. Inverness, Whispering Pines Park jogging trail. 24 Apr 1985. *Mawhinney s.n.* (USF); 4 mi W of Hwy 41 on N side of Hwy 488, T.17, R. 17, Sect. 1. 9 Jun 1983. *Richardson 1030* (USF). Collier Co. Audubon Country Club, W of US 41, T. 48, R. 25, Sect. 9. 12/24/90. *Burch 326 & 328* (CCNRD); Naples, E of old US 41, E of S.C.C. RR tracks. T.48, R.25, Sect. 10. 11/10/90. *Burch s.n.* (FAU); N Pelican Bay, T.48, R.25, Sect. 33. 10/28/90. *Burch s.n.* (FAU) ; T.49, R. 25, Sect. 4. 12/1/90. *Burch 333 & 335* (CCNRD) ; N Pelican Bay, T. 49, R. 25, Sect. 4. 9/25/90. *Burch s.n.* (FAU); N Naples, Pelican Ridge, E side US 41, 0.5 mi S of Vanderbilt Beach Rd, T. 48, R.25, Sect. 34. *Burch 221* (CCNRD); N of Wiggins Pass Rd., 1.5 mi E of Vanderbilt Rd., T.48, R.25, Sect. 16. 9/29/90. *Burch s.n.* (FAU); W of Conservancy E of Goodlett Rd., T.49, R.25, Sect. 33. 9/22/90. *Burch s.n.* (FAU); W of Conservancy E of Goodlett Rd., T.48, R.25, Sect. 21, 9/23/90. *Burch s.n.* (FAU); Marco Island. Sand Hill Street & State Road 92, T. 52, R. 26, Sect. 17. 9/30/90. *Burch 213* (CCNRD). Lee Co. Spanish Wells scrub, T.48, R.25, Sect. 3, 8/27/90. *Burch s.n.* (FAU).

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LITERATURE CITED

COLLIER COUNTY BOARD OF COUNTY COMMISSIONERS. 1989. Collier County Growth Management Plan. Collier County Board of County Commissioners, 2187 pp., appendices, maps.

CRISTMAN, S. P. 1988. Endemism and Florida's interior sand pine scrub. Final Project Report to Florida Game and Fresh Water Fish Commission, Tallahassee, FL.

DELANEY, K. R., R. P. WUNDERLIN, AND B. E. HANSEN. 1989. Rediscovery of *Zizyphus celata* (Rhamnaceae). Sida 13(3):325-330.

——— AND R. P. WUNDERLIN. 1989. A new species of *Crotalaria* (Fabaceae) from the Florida Central Ridge. Sida 13(3):315-324.

FLORIDA GAME AND FRESH WATER FISH COMMISSION. 1989. A comprehensive statewide wildlife habitat system for Florida: project outline. Florida Game & Freshwater Fish Comm., Tallahassee, 6 pp., appendix, and attached information specific to Collier County.

KARTESZ, J. AND R. KARTESZ. 1980. Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland. Univ. North Carolina Press, Chapel Hill.

KATZMAN, M. T. AND W. G. KALE. 1990. Tropical forest preservation using economic incentives: a proposal of conservation easements. Bioscience 40(11):827-832.

LEIGHTY, R. G., M. B. MARCO, G. A. SWENSEN, R. E. CALDWELL, J. R. HENDERSON, O. C. OLSON AND G. C. WILLSON. 1954. Soil survey (detailled reconnaissance) of Collier County, Florida. U.S. Dept. Agric., Washington, D.C. 72 pp., 8 inserts.

LONG, R. W. 1970. Additions and nomenclatural changes in the flora of southern Florida-I. Rhodora 72:17-46.

LONG, R. W. AND O. LAKELA. 1971. A Flora of Tropical Florida. University of Miami Press, Coral Gables; reprinted with some revision by Banyan Press, Miami, FL. 1976.

MULLER, J. W. 1990. Matrix of habitats and distribution by county of Rare/Endangered species in Florida. Florida Natural Areas Inventory, Tallahassee, FL.

MYINT, T. 1966. Revision of the genus *Stylisma* (Convolvulaceae). Brittonia 18:97-117.

U.S. DEPARTMENT OF AGRICULTURE. 1982. National List of Scientific Plant Names. 2 Vols. Soil Conserv. Serv., U.S. Dept. Agric. SCS-TP-159. Washington, D.C.

WOOD, D. A. 1990. Official lists of endangered and potentially endangered fauna and flora in Florida, 1 August 1990. Florida Game & Fresh Water Fish Comm., Tallahassee, 23 pp.

WUNDERLIN, R. P. 1982a. Guide to the Vascular Plants of Central Florida. University Presses of Florida, Gainesville/Univ. South Florida Press, Tampa, FL.

———. 1982b. Endangered and Threatened plant status survey. Report to the U.S. Fish and Wildlife Service, Jacksonville, FL.

WUNDERLIN, R. P. 1991, Univ. South Florida, Tampa, Pers. Commun.

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AMPHIPOD CONTRIBUTION TO WATERHYACINTH [*EICHHORNIA CRASSIPES* (MART.) SOLMS] DECAY

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*Abstract: Amphipods are often the most abundant macroinvertebrate associated with the exotic macrophyte waterhyacinth [*Eichhornia crassipes *(Mart.) Solms]. To determine the contribution of* Hyalella azteca *and* Gammarus tigrinus *to waterhyacinth decay, bags (202 um mesh) containing root or leaf litter were stocked at three densities (0, 5, and 15 per bag) and placed under waterhyacinth mats. Amphipods significantly increased ($P<0.05$) the rate of root and leaf decay. Decomposition rates (k values) ranged from 0.028 d^{-1} to 0.039 d^{-1} for leaf and from 0.008 d^{-1} to 0.011 d^{-1} for root detritus. Consumption was estimated at 0.081 mg dry leaf litter per mg dry amphipod on a daily basis. In addition to physical and chemical factors, the presence or absence of shredding amphipods may substantially influence the rate of waterhyacinth breakdown.*

THE waterhyacinth, *Eichhornia crassipes* (Mart.) Solms, may be the most notorious aquatic plant in Florida. Shortly after its introduction into the state in the 1890s, it became apparent that this South American immigrant was a nuisance. Growth rates of waterhyacinth are responsible for dry biomass production which purportedly exceed those of any terrestrial, saltwater, or freshwater vascular macrophyte (Wolverton and McDonald, 1979). Population doubling times can range from 6 to 18 days (Mitchell, 1976; NAS, 1976; Cornwell et al., 1977), and wet standing biomass often exceeds 500 mt ha^{-1} with yields near 3080 mt ha^{-1} yr^{-1} (Boyd, 1970; Wolverton and McDonald, 1979; Brower, 1980; DeBusk et al., 1981). Large mats of waterhyacinth often degrade water quality, adversely affect plant and animal communities, and hinder navigation (Lynch et al., 1957; Tabita and Woods, 1962; Guscio et al., 1965; McVea and Boyd, 1975; Brower, 1980; Gopal, 1987). Today, this plant is present in a majority of Florida's freshwater systems; in 1989, government agencies spent nearly one million dollars to control 14,000 ha of waterhyacinth statewide (Schardt, 1990).

Numerous studies have focused on waterhyacinth [Gopal (1987) reviewed 2742 references], but few have investigated the aquatic macroinvertebrates associated with this plant. O'Hara (1967) surveyed macroinvertebrates living on waterhyacinth roots in Lake Okeechobee, Florida, and found a diverse fauna and extremely high densities in comparison to benthic densities. The most common species was the amphipod, *Hyalella azteca*, which accounted for an average of 33% of the total number of invertebrates in each sample. In the St. Johns River, Florida, *H. azteca* was also found to be the dominant invertebrate associated with waterhyacinth roots, and radio-isotope (P-32) investigations indicated that this amphipod consumed both living and dead root tissue (Hansen et al., 1971).

Macroinvertebrates that shred and consume dead plant material often play an important role in the litter decomposition process (Webster and Benfield, 1986). Amphipods, which often act as shredders, have been shown to significantly increase decay of macrophytes, sometimes by as much as 30% (Newman et al., 1987; Newman, 1990).

Waterhyacinth decomposition has been studied in natural and man-made aquatic systems (DeBusk, 1982; DeBusk and Dierberg, 1984; Ogwada et al., 1984), but the influence of shredding invertebrates has never been quantified. Since shredding amphipods are often the predominant invertebrate among waterhyacinth roots, they may be an important component to decomposition and subsequent nutrient cycling. The purpose of this study was to determine whether amphipods had a significant effect on waterhyacinth leaf and root litter decay in a spring-fed river system.

STUDY SITE—The St. Marks River is located in the karst area of Wakulla County, Florida (30°16'N, 84°08'W). It is spring fed (20° C), runs for approximately 20 miles through flat coastal woodlands, and empties into Apalachee Bay. Sampling was conducted in the basin area (Fig. 1), a relatively wide (130 m) and shallow (1 m) portion where the river re-emerges from underground. This area provides favorable conditions for waterhyacinth production. Brazilian elodea (*Egeria densa* Planch) also is abundant and often reaches the surface, resulting in plant islands which act to channelize flow. Waterhyacinth commonly colonizes these plant islands, but it is more abundant along the river banks. During baseflow periods, water clarity is high. However, major rain events usually flush tannic water from surrounding swamps, causing the color of the river water to increase substantially. Bottom substrates consist of sand mixed with varying quantities of detrital matter, and large limestone slabs.

MATERIALS AND METHODS—On July 12, 1989, living leaves and roots were cut from waterhyacinth plants within the basin area and brought back to the Department of Natural Resources Aquatic Plant Laboratory. Living, even aged tissue was chosen to best attain physical and chemical equivalence among plant samples. Authentic senescing aerial tissue was not practical to use as litter because of the ununiform condition and difficulty of aging individual leaves and stems.

It is possible that waterhyacinth is chemically defended against consumption by certain herbivorous invertebrates. However, such noxious compounds are lost from aquatic plant material upon senescence or death (Otto and Svensson, 1981; Hay and Fenical, 1988; Newman et al., 1990). Therefore, it is likely that any defensive chemicals that may have been present initially in harvested waterhyacinth tissue did not have a long lasting effect on amphipod consumption.

Root tissue was gently rinsed to remove fine organic matter and attached invertebrates. Leaves and roots were spread out on towels for 24 hours at room temperature to evaporate excess surface moisture. Eighty labeled fine mesh (202 um) bags were each filled with approximately 18 grams (wet) of leaf litter, and another eighty with about 22 grams (wet) of root litter; contents were weighed to the nearest 0.01 g (methods similar to Newman et al., 1987). An additional 15 bags of each litter type were constructed and set aside for computation of wet weight to ash free dry weight (AFDW) conversions.

Two days after plant collection, amphipods (*Hyalella azteca* and *Gammarus tigrinus*) were collected from the study site by vigorously shaking individual waterhyacinth plants in a partly-submerged sieve bucket. Specimens were then removed from the bucket, counted, and placed in petri dishes. The ratio of *H. azteca* to *G. tigrinus* on individual plants was usually about 1:1. Immediately, amphipods (mean individual weight =1.6 mg dry, S.D.=0.37, n=10) were removed

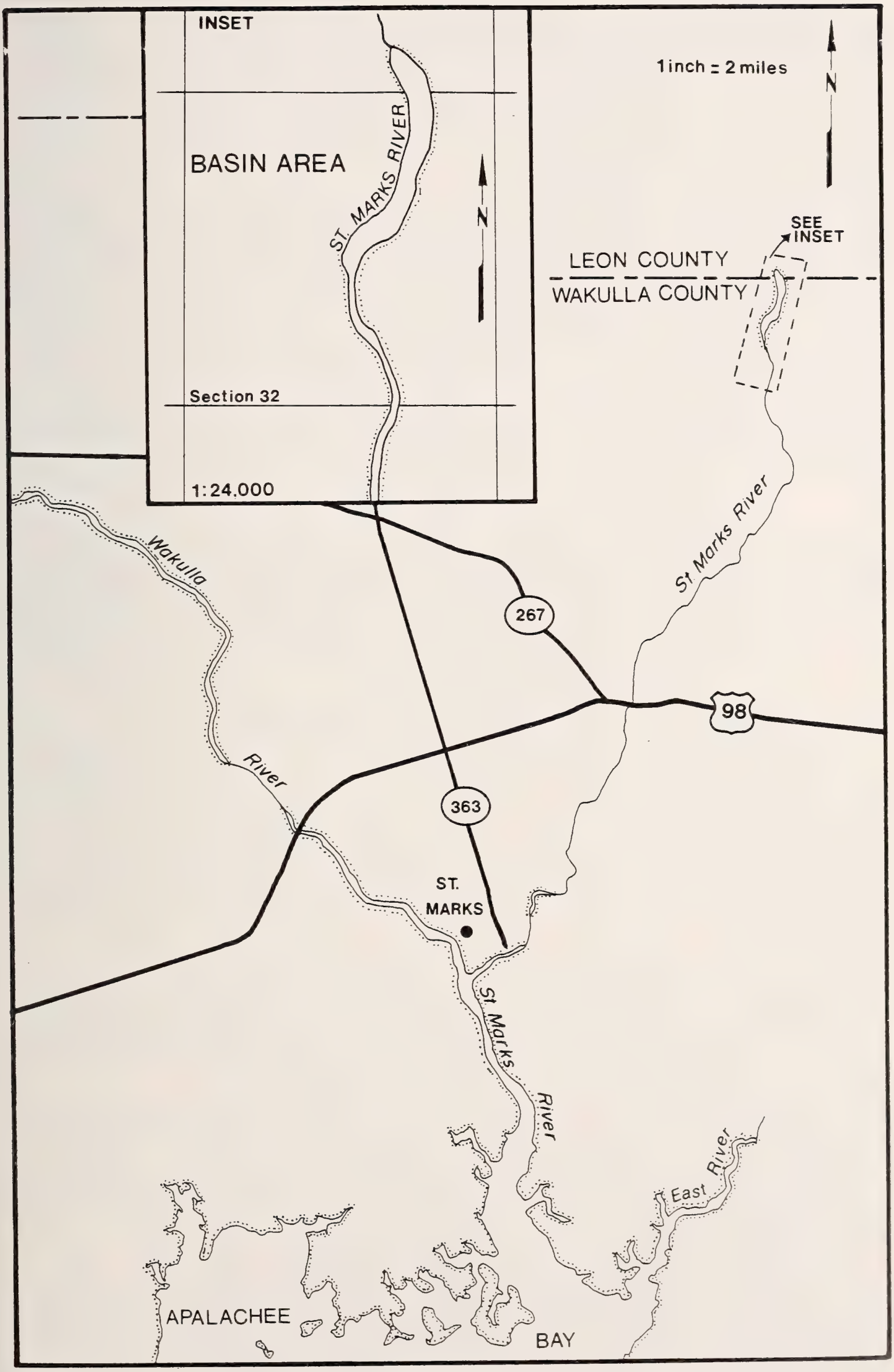

FIG. 1. Map of St. Marks River.

from the dishes and stocked (at about the same ratio) into litter bags at two densities. Forty bags of each litter type were heat sealed without amphipods; 20 bags of each litter type were stocked with 5 amphipods and 20 bags were stocked with 15 amphipods. Litter bags were then fastened to 20 pieces of nylon rope, 4 root and 4 leaf bags on each, and randomly placed under 5 waterhyacinth mats in the basin. One randomly chosen rope from each mat was withdrawn on days 17, 38, 53, and 67. This resulted in 5 replicates for the 5 and 15 amphipod treatments. Since control bags were duplicated on each rope, values from each set of 2 bags were averaged, resulting in 5 replicates for the control (0 amphipods).

Collected bags were brought back to the lab and gently rinsed under tap-water. Stocked amphipods were removed from the litter. Litter was placed in individual aluminum pans and dried at 60° C for at least 48 hours. Dry weights were recorded, then samples were ashed at 525° C for four hours. Percent of litter remaining ($AFDW_t/AFDW_0$) was determined for each bag.

Decay models were computed for each litter type and treatment using the linear regression (forced zero intercept) of $\ln(AFDW_t/AFDW_0)$ on time (days) (Petersen and Cummins, 1974). Although other models may be well suited for these data, this model provides one number that describes litter breakdown and, because it is the standard (Webster and Benfield, 1986), results can be easily compared among studies.

To compare decay coefficients (k= -slope) between controls and treatments, two regression models, one from pooled data (Eqn. 1) and one that includes a dummy variable designating treatment (Eqn. 2), were constructed for each test:

$$NH_{(\text{model } 1)}: Y=B_1 X \quad \text{(k values are similar)} \tag{1}$$

$$AH_{(\text{model } 2)}: Y=B_1 X + B_2 TX \quad \text{(k values differ)} \tag{2}$$

where Y is the ln of percent litter remaining (AFDW, g), X is days exposed (or submerged in water), and T is the treatment (dummy variable, 0 or 1). Intercepts were forced through zero, and therefore, absent in each equation. An F-test (Eqn. 3) was then used to determine the significance ($P<0.05$) of the added variable (test of equal slopes, Weisberg, 1985):

$$F_{(dfNH-dfAH,\ dfAH)}=\frac{(RSS_{NH}-RSS_{AH})\ /\ (df_{NH}-df_{AH})}{RSS_{AH}\ /\ df_{AH}} \tag{3}$$

where RSS is the residual sum of squares and df is the degrees of freedom.

RESULTS—Most amphipods stocked into litter bags persisted throughout the experiment; survival was near 75% for both litter types. In some bags, reproduction occurred and a few newly hatched amphipods were present. Since reproduction was not common, and early instar amphipods were small, the initial stocking numbers (5 and 15 amphipod treatments) were not adjusted.

Amphipods increased the rate of waterhyacinth leaf decomposition. Mean decay rates for the control, 5 and 15 amphipod treatments were 0.028 d^{-1}, 0.032 d^{-1}, and 0.039 d^{-1}, respectively. Decay rates for both treatments were higher ($P<0.05$) than the control, and leaf litter decayed faster ($P<0.05$) in bags with 15 versus bags with 5 amphipods (Table 1a).

Decay of waterhyacinth root litter was slower ($P<0.001$) than that of leaves. In the absence of amphipods, mean root litter decay was 0.008 d^{-1}. For both stocking levels, mean decay rate increased to 0.011 d^{-1}; a comparison of the regression lines indicated that both treatment decay rates (0.011 d^{-1}) were significantly higher ($P<0.05$) than the control (Table 1b).

A multiple regression of the change in litter weight versus days exposed and the number of amphipod-days (days exposed X the total dry weight of amphipods in mg) was used to estimate the rate of amphipod litter consumption. In this equation (Eqn. 4), days exposed is designated a variable to account for decomposition independent of shredders (i.e., mechanical and microbial), and amphipod days was necessary to estimate a daily amphipod influence on decomposition (Newman, 1990). Percent remaining and days were transformed in the model to correct for nonlinearity:

$$SR= -7.88 \times 10^{-1} + 1.08 \ln\#Day + 8.1 \times 10^{-5} ADay \qquad (4)$$
$$R^2=0.94$$

where SR is the ARCsin of the square root of percent litter remaining (AFDW,g), ln#Day is the natural log of day exposed, and ADay is the number of amphipod days. The overall equation was highly significant ($P<0.0001$) as well as the ADay coefficient ($P<0.0001$). By graphing the residuals (Weisburg, 1985), it was apparent that the variances were constant. A Runs test (Bradley, 1968) showed no autocorrelation, and data were normally distributed (Shapiro and Wilk, 1965). Amphipods (per mg dry weight) consumed an estimated 0.081 mg (SE = 0.019) dry leaf litter per day. A regression model for root litter was not reported because the ADay consumption coefficient was not significant ($P>0.05$).

TABLE 1. Computations for waterhyacinth decomposition data. Two regression models (forced zero intercept) were constructed for each test, one from pooled data and one that included a variable (TX) designating treatment. An F-test was then used to determine the significance of the variable TX (test of equal slopes, Weisberg, 1985). RSS=Residual Sum of Squares, and d.f.=degrees of freedom.

a. Waterhyacinth leaf decay			
		Estimate (t-Value)	
Test	Variable	Model 1 [Pooled]	Model 2
Control vs. 15 amphipods	Day	–0.033(–22.8)	–0.039(–22.5)
	TX	—	0.011(4.6)
	RSS	9.52	6.58
	d.f.	49	48
	F=21.5, P<0.01		
Control vs. 5 amphipods	Day	–0.030(–30.6)	–0.032(–23.9)
	TX	—	0.004(2.1)
	RSS	4.19	3.82
	d.f.	49	48
	F=4.6, P<0.05		
5 amphipods vs. 15 amphipods	Day	–0.036(–23.0)	–0.039(–18.9)
	TX	—	0.007(2.5)
	RSS	10.58	9.34
	d.f.	49	48
	F =6.4, P<0.05		
b. Waterhyacinth root decay			
Control vs. 15 amphipods	Day	–0.009(–17.2)	–0.011(–14.0)
	TX	—	0.002(2.1)
	RSS	1.33	1.22
	d.f.	49	48
	F=4.3, P<0.05		
Control vs. 5 amphipods	Day	–0.009(–23.5)	–0.011(–19.7)
	TX	—	0.002(3.0)
	RSS	0.67	0.56
	d.f.	48	47
	F=8.7, P<0.05		

DISCUSSION—Comparison of decay rates between the control and treatments clearly indicated that amphipods accelerated waterhyacinth litter breakdown. Stocked *G. tigrinus* and *H. azteca*, 15 per bag, accounted for 28 and 18% of total decay (at day 67) of leaf and root litter, respectively. However, the influence of amphipods on root litter breakdown may be underestimated. On the last sampling date (day 67) over 50% root litter remained; a continuation of the trial until less than 20% litter remained would have possibly increased the estimate of amphipod influence, since shredder contribution to decay increases over time of exposure (Herbst, 1982; Pearson and Tobin, 1989).

The magnitude of amphipod influence on waterhyacinth decay in this study is similar to findings reported for other shredder species consuming other litter types. Cummins and co-workers (1973) found the shredders *Tipula* (Diptera) and *Pycnopsyche* (Trichoptera) accounted for 16 to 33% of hickory (*Carya glabra*) decay in artificial streams. By eliminating macroinvertebrates from a small stream with an insecticide and making comparisons (between and within stream), Wallace and co-workers (1986) estimated shredder [mostly *Peltoperla* (Plecoptera), *Pycnopsyche*, and *Tipula*] influence on litter breakdown to be 22-28%. In a laboratory experiment, Pearson and Tobin (1989) reported that caddisfly larvae (*Anisocentropus* sp.) accelerated the decomposition of *Ardisia brevipedata* leaves by 35 to 83%. In two different experiments, Newman and co-workers (Newman et al., 1987; Newman, 1990) found that stocked amphipods accounted for 11 to 26% of curled pondweed (*Potamogeton crispis*) breakdown (210 um litter bags) in experimental streams, and near 11% breakdown (200 um bags) of watercress (*Nasturtium officinale*) in a natural stream.

Prior to this study, macroinvertebrate contribution to waterhyacinth decay had not been investigated, and furthermore, studies that have determined overall waterhyacinth decomposition rates in natural systems are few. Litter bags placed under waterhyacinth mats in the St. Marks River had 16% leaf and 56% root litter remaining at day 67 (controls with zero amphipods). DeBusk and Dierberg (1984), using large (30 X 30 cm) 2-mm mesh bags filled with approximately 200 g (wet) litter, found that about 30% waterhyacinth aerial tissue remained after 67 days exposure in a south Florida lake. The comparatively slower decay, even with bags of substantially larger mesh, was likely an artifact of the quantity of initial litter used. In this study, much smaller bags were filled with 18 to 22 g (wet) of litter. Generally, there is an inverse relationship between size of litter packs and the rate of decay (Reice, 1974; Benfield et al., 1979). Hammerly and co-workers (1989) determined waterhyacinth breakdown in two Argentinean rivers. Decay rates for root and leaf litter combined (1 mm bags) were 0.012 d^{-1} in the mid-channel of a slow moving river (0.03 m s^{-1}) and 0.043 d^{-1} in a fast flowing (0.6 m s^{-1}) river. Accelerated mechanical fragmentation of litter in the swift currents of the fast flowing river was suggested as the cause of significantly higher decay.

Although the methodologies differ, my decay rates of 0.028-0.039 d^{-1} for leaves and 0.008-0.011 d^{-1} for roots are comparable to the findings in Argentina.

My estimate of amphipod consumption of waterhyacinth leaf litter (0.081 mg dry day^{-1}) is similar to other consumption estimates reported for *Gammarus pseudolimnaeus*. Newman (1990) found *G. pseudolimnaeus* to consume 0.08 to 0.12 mg (dry) watercress per day in fine mesh (202 um) bags. *G. pseudolimnaeus* has also been shown to consume terrestrial leaf litter at similar rates (Herbst, 1982; Bird and Kaushik, 1985).

The extreme ability of waterhyacinth to grow is accompanied by the potential for high detritus output. In central and south Florida, waterhyacinth mats released 2 to 3.5 g dry m^{-2} day^{-1} to the detrital pool under varying nutrient conditions (DeBusk et al., 1983; Moorhead et al., 1988; DeBusk and Dierberg, 1989). Detritus deposited from waterhyacinth mats has been found to mostly consist of root material (80 percent); senescing aerial tissue remains near the surface of the water column around living plants (DeBusk et al., 1983). It is plausible that dead, floating leaf and stem material is actively consumed by amphipods associated with living waterhyacinth plants. These invertebrates may be integral in nutrient cycling and energy transfer, since they are usually the most abundant (O'Hara, 1967; Hansen et al., 1971; Bartodziej, unpublished data) and are able to consume substantial quantities of waterhyacinth leaf detritus. It is less likely that amphipods living amongst waterhyacinth plants are important to dead root breakdown, since this material readily falls away from living plants, and therefore, is more accessible to benthic invertebrates.

In laboratory toxicity studies, amphipods seem to be tolerant to the most common herbicide used to control waterhyacinth. In 1989, over 14,000 ha of waterhyacinth were chemically treated (about 90 percent with amine salts of 2,4-dichloro-phenoxyacetic acid) in Florida's freshwaters (Schardt, 1990). The expected environmental concentration of 2,4-D (amine) ranges from 0.03 to 0.22 mg l^{-1} when applied at label rate. Since standard 96-h LC_{50} values are substantially higher (100 mg l^{-1}) than expected environmental concentrations, amphipods are probably not directly impacted from field applications of 2,4-D (Johnson and Finley, 1980). However, the effects of habitat loss on this invertebrate are unknown. It is also unclear as to whether these generalist shredders consume or avoid detritus produced from herbicide treatments. Considering their estimated consumption rate, amphipods may be important to the breakdown of this material as well as detritus originating from natural turnover. More quantitative observations of amphipods functioning in the waterhyacinth micro-environment and measurements of possible secondary effects of herbicides on this invertebrate will help in the understanding of detritus dynamics in waters under chemical plant management programs.

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LITERATURE CITED

Benfield, E. F., R. W. Paul, and J. R. Webster. 1979. Influence of exposure technique on leaf breakdown rates in streams. Oikos 33:386-391.

Bird, G. A. and N. K. Kaushik. 1985. Processing of elm and maple leaf discs by collectors and shredders in laboratory feeding studies. Hydrobiologia 126:109-120.

Boyd, C. E. 1970. Vascular aquatic plants for mineral nutrient removal from polluted water. Econ. Bot. 24:95-103.

Bradley, J. V. 1968. Distribution-free Statistical Tests. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Brower, W. W., II. 1980. Biological and physical investigations of bodies of water beneath dense water hyacinth populations before and after chemical treatment. Ph.D. dissert., Univ. Florida, Gainesville.

Cornwell, D. A., J. Zoltec, Jr., C. D. Patrinely, T. des Furman, and J. I. Kim. 1977. Nutrient removal by waterhyacinth. J. Water Pollution Cont. Fed. 49:57-65.

Cummins, K. W., R. C. Petersen, F. O. Howard, J. C. Wuycheck, and V. I. Holt. 1973. The utilization of leaf litter by stream detritivores. Ecology 54:336-345.

DeBusk, T. A., 1982. Standing crop changes, detritus production and decomposition of *Eichhornia crassipes* (Mart.) Solms. Masters thesis, Florida Institute of Technology, Melbourne. 93 pp.

———— and F. E. Dierberg. 1984. Effect of nitrogen and fiber content on the decposition of the waterhyacinth (*Eichhornia crassipes*). Hydrobiologia 118:199-204.

———— and F. E. Dierberg. 1989. Effects of nutrient availability on water hyacinth standing crop and detritus decomposition. Hydrobiologia 174:151-159.

————, J. H. Ryther, M. D. Hanisak, and L. D. Williams. 1981. Effects of seasonality and plant density on the productivity of some freshwater macrophytes. Aquat. Bot. 10:133-142.

————, L. D. Williams, and J. H. Ryther. 1983. Removal of nitrogen and phosphorus from wastewater in a waterhyacinth-based treatment system. J. Environ. Qual. 12:257-262.

Gopal, B. 1987. Waterhyacinth. Elsevier Science Publishers, Amsterdam, The Netherlands.

Guscio, F. J., T. R. Bartley, and A. N. Beck. 1965. Water resources problems generated by obnoxious plants. J. Waterways Harb. Div., Am. Soc. Civil Eng. 10:47-60.

Hammerly, J., M. Leguizamon, M. A. Maine, D. Schiver, and M. J. Pizarro. 1989. Decomposition rate of plant material in the Parana Medio River (Argentina). Hydrobiologia 183:179-184.

Hansen, K. L., E. G. Ruby, and R. L. Thompson. 1971. Trophic relationships in the waterhyacinth community. Florida Scient. 35:107-113.

Hay, M. E. and W. Fenical. 1988. Marine plant-herbivore interactions: The ecology of chemical defense. Annu. Rev. Ecol. Syst. 19:111-145.

Herbst, G. N. 1982. Effects of leaf type on the consumption rates of aquatic detritvores. Hydrobiologia 89:77-87.

Johnson, W. W., and M. T. Finley. 1980. Handbook of acute toxicity of chemicals to fish and aquatic invertebrates. U.S. Fish Wildl. Serv. Res. Publ. No. 137, Washington, D.C.

Lynch, J. J., J. E. King, T. K. Chamberlain, and H. L. Smith. 1957. Effects of aquatic weed infestations on the fish and wildlife of the Gulf states. Spec. Sci. Rep. U.S. Fish Wildl. Serv. 39:1-77.

McVea, C., and C. E. Boyd. 1975. Effects of waterhyacinth cover on water chemistry, phytoplankton, and fish in ponds. J. Environ. Qual. 4:375-378.

Mitchell, D. S. 1976. The growth and management of *Eichhornia crassipes* and *Salvinia* spp. in their native environment and in alien situations. Pp. 167-175. *In:* Varshney, C. K. and J. Rzoska (eds). Aquatic weeds in South east Asia. Dr. W. Junk Publishers, The Hague, The Netherlands.

Moorhead, K. K., K. R. Reddy, and D. A. Graetz. 1988. Water hyacinth productivity and detritus accumulation. Hydrobiologia 157:179-185.

National Academy of Sciences (NAS). 1976. Making Aquatic Weeds Useful: Some perspectives for developing countries. National Academy of Sciences, Washington, DC.

NEWMAN, R. M. 1990. Effect of shredding amphipod density on watercress (*Nasturtium officinale*) breakdown. Holarctic Ecol. 13:293-299.

________, J. A. PERRY, E. TAM, AND R. L. CRAWFORD. 1987. Effects of chronic chlorine exposure on litter processing in outdoor experimental streams. Freshwater Biol. 18:415-428.

________, W. C. KERFOOT, AND Z. HANSCOM, III. 1990. Watercress and amphipods: Potential chemical defense in a spring stream macrophyte. J. Chem. Ecol. 16:245-259.

OGWADA, R. A., K. R. REDDY, AND D. A. GRAETZ. 1984. Effect of aeration and temperature on nutrient regeneration from selected aquatic macrophytes. J. Environ. Qual. 13:139-143.

O'HARA, J. 1967. Invertebrates found in water hyacinth mats. Florida Scient. 30:73-80.

OTTO, C. AND B. S. SVENSSON. 1981. How do macrophytes growing in or close to water reduce their consumption by aquatic herbivores? Hydrobiologia 78:107-112.

PEARSON, R. G. AND R. K. TOBIN. 1989. Litter consumption by invertebrates from an Australian tropical rainforest stream. Arch. Hydrobiol. 116:71-80.

PETERSEN, R. C. AND CUMMINS, K. W. 1974. Leaf processing in a woodland stream. Freshwater Biol. 4:343-368.

REICE, S. R. 1974. Environmental patchiness and the breakdown of leaf litter in a woodland stream. Ecology 55:1271-1281.

SCHARDT, J. D. 1990. Exotic plant control: A look back, a look ahead. Aquatics 12:(1)4-6.

SHAPIRO, S. S. AND M. WILK. 1965. An analysis of variance test for normality. Biometrika 52:591-611.

TABITA, A. AND J. W. WOODS. 1962. History of hyacinth control in Florida. Hyacinth Control J. 1:19-22.

WALLACE, J. B., D. S. VOGEL, AND T. F. CUFFNEY. 1986. Recovery of a headwater stream from an insecticide-induced community disturbance. J. N. Am. Benthol. Soc. 5:115-126.

WEBSTER, J. R. AND E. F. BENFIELD. 1986. Vascular plant breakdown in freshwater ecosystems. Ann. Rev. Ecol. Syst. 17:567-594.

WEISBERG, S. 1985. Applied linear regression. 2nd ed. Wiley, New York.

WOLVERTON, B. C., AND R. C. MCDONALD. 1979. Waterhyacinth (*Eichhornia crassipes*) productivity and harvesting studies. Econ. Bot. 33:1-10.

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REVIEW

Eugene Garfield, *Creativity, Delayed Perception, and Other Essays*, ISI Press (3501 Market Street, Philadelphia, PA 19104), 1991, Pp. xiv + 385. Price: $35.00.

PREMATURE discoveries—those retrospectively described as having been "ahead of their time"—are familiar enough, but how many of us have considered postmature scientific discoveries, those judged retrospectively to have been delayed (botanist Gregor Mendel is a protoypical example)? This topic, "Saxophobia," "Lupus," " Self- Promotion in Science," and 48 other unique essays challenge our view of sciences and extend our knowledge in a year of columns from Current Contents (R). The author, founder and President of the Institute for Scientific Information, provides thought-provoking essays and reviews that serve as models of good writing and information transfer. Get your favorite library to buy a copy. Better yet, buy your own copy so you'll have a chance to savor the essays again and again.—D. F. Martin, University of South Florida, Tampa.

COGONGRASS *(IMPERATA CYLINDRICA)* CONTROL WITH GLYPHOSATE[1]

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Abstract: *A stand of cogongrass was burned in February 1983, and the regrowth sprayed with 0.5, 1.0, and 2.0% solutions (v/v) of glyphosate in either April, August, or November of the same year. Plant density was estimated immediately before each treatment and again in July 1984 and 1985. Plant control with the 2% glyphosate treatment differed significantly ($p<0.05$) from the 0.5 and 1.0% solution treatments only after the November application date. Glyphosate as a 2% solution appeared to control cogongrass satisfactorily for at least 2 yr (91% mortality), while control after the August application never exceeded 40%. Controlling cogongrass in forests will be required to effectuate adequate natural regeneration of pines or survival of planted seedlings and to maintain natural diversity of plant species.*

Cogongrass (*Imperata cylindrica* (L.) Beauv.) is rapidly becoming a serious weed problem in some southeastern states. Since its accidental introduction near Mobile, AL in 1911, cogongrass has established itself throughout southern Alabama, Mississippi, and in at least 27 of Florida's 67 counties (Tanner and Werner 1986).

Cogongrass propagates rapidly, both vegetatively by developing an extensive rhizome mat and by wind-blown seed. This species has been planted along highways and canals where it is an effective soil-stabilizing grass. However, small colonies have begun to invade undisturbed sites in native pastures and forest land from the nearest highways (source). The wind evidently disperses the light, villous seeds long distances over the open, flat landscape. Once a stand of cogongrass is established, our observations are that few herbaceous or woody plant seedlings can invade or survive in these locations. The spread of cogongrass must be controlled promptly and effectively.

Although cogongrass has been controlled in agricultural fields by deep plowing (Hartley, 1949), stands of this grass in forest understories or in open range areas are managed best with herbicides. The most extensively tested and recommended herbicides for cogongrass control are Dalapon, (2,2-dichloropropanoic acid), and glyphosate, [N-(phosphonomethyl)glycine] (Dickens and Buchanan, 1975). Of these two herbicides, glyphosate is more effective on sandy soils (Yeoh and Pushparajah, 1976) that characterize most of Florida's soils where cogongrass has invaded. Additionally, effectiveness of glyphosate is greater in shaded sites (Moosavi-Nia and Dore, 1979; Wong, 1981), such as under forest canopies.

The objective of this study was to test the efficacy of glyphosate in controlling cogongrass when applied seasonally at three rates.

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[1] This is a contribution to the Florida Agricultural Experiment Station Journal Series No. 8469.

MATERIALS AND METHODS—This study was established in a longleaf pine-turkey oak (*Pinus palustris* Mill.-*Quercus laevis* Walt.) forest near Brooksville, FL, in Hernando County. Although the mature pines (*ca* 200 yr old) were tapped for turpentine production, no active timber harvesting has ever occurred on this forest tract. Soil series at the study site are primarily Arredondo fine sand of the loamy, siliceous, hyperthermic Grossarenic Paleudults. The annual, frost-free growing season averages 312 days, and average annual precipitation is 137 cm.

An experiment was designed to test the effectiveness of four application rates of glyphosate (0.0, 0.5, 1.0, and 2.0% (v/v) solutions of a 430 gm/L commercial formulation) applied at three times of the year (April, August, and November 1983) on cogongrass control. Applications were made on a spray-to-runoff basis, i.e., until solution was observed dripping off of leaves. A backpack sprayer with a hand-controlled nozzle was used. The spray solution concentrations used were those the manufacturer recommended (Anonymous, 1983); a 1.0% solution is recommended for most circumstances, but a 2.0% solution is recommended for some perennials.

At the time of the study several solid stands of cogongrass, 0.5 to 2 ha in size, were located within the forest. The experimental study site was placed within one of these homogeneous stands. The study site received a prescribed fire in February 1983 to remove senescent plant material and to stimulate plant regrowth. At each of the three times of application, four replicates of each of the four herbicide treatments were allocated within a 7 plot by 7 plot grid using a completely random experimental design. Each square plot was 4 m on a side and was separated from adjacent plots by 1-m borders of untreated vegetation.

Cogongrass tillers were counted in two, permanently-marked, 0.9-m^2, circular quadrats located within each experimental plot. Counts were made immediately prior to each treatment and again in August 1984 and July 1985, following 1 and 2 growing seasons, respectively. Percent mortality associated with each treatment was estimated by comparing pre- and post-treatment tiller counts within the permanently-marked quadrats.

Because the completely randomized study design was replicated by time of application (but not space), the data were analyzed as a series of experiments (Cochran and Cox, 1950). Count data were transformed by the square root procedure. Both count data and tiller mortality rates were compared among the herbicide treatments using analysis of covariance, with the 1983 pretreatment counts as the covariable. Least-square-mean, pair-wise comparisons were used to determine the effectiveness of the four herbicide rates. Only the unadjusted tiller mortality means are reported because the mortality trends were statistically the same as those of the transformed and adjusted, least-square data.

RESULTS AND DISCUSSION—After the February 1983 fire, cogongrass plant density in the check plots (0.0 % treatment) increased from April 1983 (average=71 plants/m^2) to August 1984 (average=82 plants/m^2), but then declined in November 1985 (average=65 plants/m^2) (Table 1). Plant density on the check plots at this study was much lower than the densities of 1000-1200/m^2 reported on road sides in southern Alabama (Dickens and Buchanan, 1975). Low plant densities at this study may have been due to the partial shading of overstory pines and oaks, a relationship demonstrated by Eussen (1976), or to the prescribed fire.

Percent mortality of cogongrass plants one growing season after herbicide application in the spring was significantly greater in the 1.0 and 2.0% treatments than in the 0.0 and 0.5% treatments (Table 1). After two growing seasons natural mortality (32%) in the check plots (April application) was still less than mortality in the other three treatments. There was no significant difference among the mortality rates in 0.5, 1.0, and 2.0 treatment rates.

Glyphosate applied in summer resulted in little to no reduction in cogongrass plant density, regardless of application rate or time since treatment (Table 1). Plots receiving the 0.5% rate actually showed an increase in plant density in comparison to check plots.

TABLE 1. Mean number of living congongrass plants immediately before three rates of glyphosate application on three dates, and the percent mortality one and two growing seasons later, Hernando County, FL.

Glyphosate treatment	Rate (%)	Sampling date[a] Before treatment Live plants (no./M^2)	Aug. 9, 1984 Mortality (%)	July 29, 1985 Mortality (%)
April 13, 1993	0.0	72	16*	32*
	0.5	83	15*	46
	1.0	57	49	46
	2.0	71	54	56
		Avg. 71		
August 23, 1983	0.0	84	18*	38
	0.5	76	+12*	10*
	1.0	73	27	37
	2.0	94	39	39
		Ave. 82		
November 18, 1983	0.0	57	+13*	16*
	1.0	73	13*	33*
	1.5	64	51*	63*
	2.0	65	80	91
		Avg. 65		

[a] Mean mortality values within a column for each separate treatment date followed by an asterick are significantly lower ($p<0.5$) than the label-recommended, 2.0%-application rate according to pair-wise comparison *t*-tests.

Cogongrass plant mortality was highest following the November application time (Table 1). Mortality continued to increase at all three rates of application between the first and second post-treatment growing seasons. At both post-treatment sampling dates, tiller mortality in plots receiving the 2.0% application rate was significantly greater than in the other three treatments with only 9% of the tillers surviving after two growing seasons.

Due to the ability of cogongrass to spread rapidly from rhizomes, all tillers and rhizomes must be killed before control can be considered successful. In this study even the highest level of mortality (91% following 2% glyphosate treatment) would require sequential treatments to eliminate the grass completely. However, this high level of initial stand reduction would reduce the cost of follow-up treatment.

Burning the test plots before the herbicide treatment removed all standing dead cogongrass and stimulated regrowth. Succulent cogongrass regrowth was hypothesized to be more susceptible to glyphosate action at reduced concentrations. However, glyphosate concentrations of less than the recommended label rate for perennials (2.0% v/v) did not kill succulent regrowth effectively. The net direction of carbohydrate translocation, though not measured in this study, may have been a critical factor in reducing the amount of herbicide translocated to the rhizomes.

CONCLUSIONS—Given that cogongrass is a relatively tall (1.0-1.5 m), mat-forming grass that is well adapted to the environment of the southeastern United States, control of its current and future spread is needed to protect the ecological integrity of this region's forest and range lands. Results of this study indicate that glyphosate, when applied in a 2.0% (v/v) solution in the fall following a spring burn, will give good to excellent control for at least 2 yr. Continued treatment of residual living plants, however, will be necessary to assure long-lasting eradication of this species. Burning, or some other type of top removal, of cogongrass stands to remove standing dead plant material prior to herbicide application, should reduce the total amount of herbicide needed to treat a stand of grass.

LITERATURE CITED

ANONYMOUS. 1983. Specialty applications guide for ROUNDUP herbicide. Monsanto Company, St. Louis, MO. RUP-NC-83-L-05.

COCHRAN, W. G. AND G. M. COX. 1950. Experimental Designs. John Wiley & Sons, New York.

DICKENS, R. AND G. A. BUCHANAN. 1975. Control of cogongrass with herbicides. Weed Sci. 23:194-197.

EUSSEN, J. H. H. 1976. The effects of light intensity on some growth characteristics of alang-alang, (*Imperata cylindrica* (L.) Beauv.) BIOTROP Bull. 10.

HARTLEY, C. W. S. 1949. An experiment on mechanical methods of lalang eradication. Malay. Agri. J. 32:236-252.

MOOSAVI-NIA, H. AND J. DORE. 1979. Factors affecting glyphosate activity in *Imperata cylindrica* (L.) Beauv. and *Cyperus rotundus* L. 2. Effect of shade. Weed Res. 19:321-327.

TANNER, G. W. AND M. R. WERNER. 1986. Cogongrass in Florida...an encroaching problem. Fla. Coop. Ext. Serv. Fact Sheet WRS-5.

WONG, P. W. 1981. Evaluation of the isopropylamine salt of glyphosate for *Imperata cylindrica* (L.) Beauv. control in oil palm. Proc. Asian-Pac. Weed Sci. Soc. Conf. 8:273-276.

Yeoh, C. H. and E. Pushparajah. 1976. Chemical control of *Imperata cylindrica* (L.) Beauv. (lalang) in Malaysia. P. 250-273 *In:* Proc. Rubber Res. Inst. Malaysia Planters' Conf., Kuala Lumpur, Malaysia.

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STUDYING A SPECIES IN DECLINE: CHANGES IN POPULATIONS OF THE GOPHER TORTOISE ON FEDERAL LANDS IN FLORIDA

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ABSTRACT: *In 1987-88, 14 populations of the gopher tortoise,* Gopherus polyphemus *(Daudin), residing on federal lands in Florida were surveyed. These populations had been surveyed in 1978-79. For the five lands for which surveys could be compared, it was found that the percent of burrows that were active increased on one of the lands, decreased on another, and remained about the same on the other three. No systematic differences in size distributions between surveys were correlated with the changes in the percent of burrows that were active. For two sites that were sampled completely, Everglades National Park and J.N. "Ding" Darling National Wildlife Refuge, the data permitted a more precise evaluation of the differences in size distributions between surveys. This evaluation clearly illustrated that substantial, and potentially detrimental, changes in population structure have taken place on at least one federal land. Because at least one population appeared to have declined, residence on "protected" land cannot be assumed to assure the continued existence of a population. It follows that gopher tortoise populations even on reserves need continuous monitoring and management to prevent their decline.*

THE gopher tortoise, *Gopherus polyphemus* (Daudin), ranges from Louisiana, through Mississippi, Alabama, Florida, and Georgia, to South Carolina. It occupies habitats with a sandy substrate suitable for construction of its extensive burrows. Unfortunately, its preference for such habitats brings the tortoise directly into conflict with human interests. In Florida, for example, vast areas of important tortoise habitats such as longleaf pine/turkey oak ("sandhill"), sand pine/scrub oak ("scrub"), and coastal dunes, have been destroyed or degraded in favor of agriculture, development, recreation, and other uses (Diemer, 1986). Substantial populations of the gopher tortoise remain on various management areas throughout Florida, however.

Eberhardt (1988) pointed out the value of multiple management areas in providing an "opportunity for the level of replication needed for bona fide statistical tests" of management procedures. He suggested that such tests (of null models) might be done retrospectively, using available data. We attempted to use an approach like the one suggested by Eberhardt (1988) to understand the changes that take place in isolated populations of the gopher tortoise, using data collected in the late 1970s and in the late 1980s.

SITES AND METHODS—The gopher tortoise inhabits a number of federal lands in Florida. None of these lands was obtained by the federal government primarily for the well-being of tortoises, nor with the intent of conserving habitats important to them, but resident tortoises are protected simply by virtue of their presence on these lands. Logan (1979) surveyed gopher tortoise populations on 17 federal lands in 1978-79, and we surveyed a subset of 14 of them in 1987-88 (Table 1). We did not survey Caloosahatchee National Wildlife Refuge (N.W.R.), Hobe Sound N.W.R, or Loxahatchee N.W.R., because they had no tortoises at all or only small introduced populations, according to their managers.

TABLE 1. Federal lands surveyed by Logan (1978-79) and by us (1987-88). Method is the way in which burrows were sampled: A=complete survey; B=7-m-wide, variable-length, belt transect survey; C=7-m X 150-m belt transect survey. Area estimates are given in hectares, and number estimates are of resident tortoises, calculated from numbers of burrows (see text). ND=not determined, NR=included in Merritt Island N.W.R. survey, NS=not surveyed.

Location	1978-79			1987-88		
	Method	Area	Number	Method	Area	Number
Caloosahatchee N.W.R	A	1	8	NS	–	–
Canaveral N.S.	NR	–	–	B	–	–
Cedar Keys N.W.R.	A	4	5-10	A	<1	14
Chassahowitzka N.W.R.	B	14	85	A	2	37
Egmont Key N.W.R.	B	133	1580	B	92	2128
Everglades N.P.	C	80	470	B	85	1137
Fort Matanzas N.M.	A/B	26	65	A	11	118
Gulf Islands N.S.	B	ND	0-50	–	–	0
Hobe Sound N.W.R.	B	ND	0-20	NS	–	–
J.N. "Ding" Darling N.W.R.	A	ND	60	A	10	34
Lake Woodruff N.W.R.	C	154	100	A/B	20	77
Loxahatchee N.W.R.	A	ND	1	NS	–	–
Merritt Island N.W.R. (including Canaveral N.S.)	C	12,300	13,800	B/C	7085	57,990
Ocala N.F.	C	122,700	42,500	C	10,295	39,253
St. Johns N.W.R.	A	4	5-10	A	<1	4
St. Marks N.W.R.	C	2262	2500	C	733	3472
St. Vincent N.W.R.	A	ND	5-10	A	13	13

We compared population data for only five of these federal lands (Chassahowitzka N.W.R., Everglades National Park (N.P.), Fort Matanzas National Monument (N.M.), J.N. "Ding" Darling N.W.R, Lake Woodruff N.W.R.), however, because several difficulties prevented our comparing data for the other nine lands. Three of the lands supported gopher tortoise populations too small to provide meaningful comparisons through time. Cedar Keys N.W.R., St. Johns N.W.R., and St. Vincent N.W.R. probably supported fewer than fifteen tortoises each at the times of both surveys. Even substantial changes may occur by chance in such small populations. Two other lands supported populations too large to provide meaningful comparisons. Merritt Island N.W.R. and Ocala National Forest (N.F.) probably supported more than 10,000 tortoises each at the times of both surveys. Sample sizes were so relatively small in both cases that substantial sampling errors may have yielded spurious estimates of population sizes and burrow size distributions. We did not compare data for Gulf Islands N.S., because we found no gopher tortoise burrows there. The population data that we employed to make comparisons, numbers and sizes of active, inactive, and abandoned burrows (see below), were not available from Logan for the other three lands (Canaveral National Seashore (N.S.), Egmont Key N.W.R., St. Marks N.W.R.).

Information on tortoise populations was obtained by Logan (1979) and by us from examination of tortoise burrows. Burrow widths correlate strongly with the carapace lengths of the tortoises inhabiting them (e.g., Alford, 1980; Martin and Layne, 1987) and, therefore, the size distribution of burrow widths accurately reflects the size distribution of carapace lengths of resident gopher tortoises. In both studies, examination of burrows was made during the warm, moist times of the year when tortoises are prone to leave their burrows and move about aboveground.

Three methods were employed to survey burrows both in Logan's study (1979) and ours. The choice of method for a particular location depended largely on the extent of potential tortoise habitat. Complete surveys usually were employed for relatively small areas, 7-m-wide belt transects of variable length for moderately sized areas, and 7-m X 150-m belt transects for relatively large areas (Table 1). We did not necessarily use the same method as Logan for a particular location (Table 1); often, we employed a more labor-intensive method than did Logan (1979), simply because labor was available to us. The use of belt transects has been criticized on the grounds that the method is biased: the farther an object is from the center of the transect, the less likely it is to be spotted (e.g., Burnham and Anderson, 1984; Burnham et al., 1985). This problem may have caused Logan, who worked alone, to underestimate the density of burrows, especially small ones, in some cases; but we employed three researchers walking abreast to search the entire width of each transect.

We were conservative in our estimates of available habitat, including only those areas where actual presence of tortoises was confirmed by signs of activity. Our restrictive criterion no doubt caused our estimates of available habitat to be lower, in general, than those of Logan (1979).

Burrows encountered during both surveys were classified as "active," "inactive," or "abandoned" (Auffenberg and Franz, 1982). Active burrows showed evidence of recent tortoise activity, such as footprints around the entrance or scrape-marks within the burrow caused by the plastron abrading the sand. Inactive burrows potentially could be used by a tortoise but lacked evidence of recent tortoise activity. Abandoned burrows could not be used by a tortoise without modification, because they were overgrown or damaged. Logan (1979) measured burrow widths with a tape measure, a ruler, or a caliper. We measured burrow widths, to the nearest 0.5 cm, with a pair of meter sticks, fastened together at the 50-cm mark to form a connected pair of calipers. The meter sticks were placed into a burrow to a depth of 50 cm and spread open so that one stick touched each side of the burrow, allowing the width of the burrow to be measured across the external ends of the sticks. Because Logan (1979) measured burrow width across the entrance and we measured it at 50-cm depth, it is likely that Logan's measurements are systematically larger than ours, because burrow entrances tend to become eroded. A small systematic difference between Logan's measurements and ours would not impinge much upon our conclusions, however, because both sets of data were divided into broad categories of burrow width for analysis.

RESULTS—Population sizes of tortoises usually are estimated from numbers of burrows by the method of Auffenberg and Franz (1982): total number of active and inactive burrows is multiplied by 0.614. Although we do not believe this method provides reliable absolute estimates of population sizes in all cases (Burke, 1989; Mushinsky and McCoy, 1992), we used it to allow comparison of our results with those of Logan (Table 1). The population sizes of tortoises residing on federal lands in Florida appear in some cases to have changed dramatically in the decade between surveys; however, the differences between the results of the two surveys may indicate no more than differences in transect method employed (see above) or in estimates of available habitat. Even though our estimates of available habitat were lower, in general, than those of Logan (1979), our estimates of population sizes were not systematically lower than his (Table 1). Because the two sets of estimates of population sizes were derived from data gathered in different ways, we view this result with caution.

TABLE 2. Estimated percentage of burrows in three categories of activity (active, inactive, abandoned; see text), for five federal lands in Florida surveyed by Logan (1978-79) and by us (1987-88). Estimates for Fort Matanzas N.M. in the first survey are for two classes (active + inactive, abandoned). Asterisks indicate data obtained by transect surveys.

Location	Percent of Burrows					
	1978-79			1987-88		
	Act.	Inact.	Abd.	Act.	Inact.	Abd.
Chassahowitzka N.W.R.	70*	14*	16*	66	28	6
Everglades N.P.	55*	25*	20*	66*	25*	9*
Fort Matanzas N.M.	—88*—		12*	51	29	20
J.N. "Ding" Darling N.W.R.	43	23	34	10	35	55
Lake Woodruff N.W.R.	35*	35*	30*	69*	28*	3*

Convincing documentation of changes that might have occurred in the sizes of these populations in the last decade requires data that can reveal changes in population sizes in a reliable manner throughout all of the federal lands. As tortoise population sizes were estimated from counts of burrows of different statuses, the requisite data are numbers of active, inactive, and abandoned burrows. Furthermore, understanding the reasons behind any changes in population size that did occur between surveys requires additional information, data on demographic shifts. For our purposes, these data would be changes in size distributions of burrows between surveys.

We examined changes during the decade in the relative numbers of active, inactive, and abandoned burrows, for the five federal lands for which such data were available (Table 2). Assuming that burrows within these three categories are found in proportion to their actual frequencies of occurrence and that the determination of categories was relatively consistent between studies, large shifts among categories may signal important changes in a population. Only relatively small changes in percentages of burrows within the three categories are evident for Chassahowitzka N.W.R. (4% decrease in active burrows), Everglades N.P. (11% increase in active burrows), and Fort Matanzas N.M. (8% decrease in active + inactive burrows). In contrast, relatively large changes in percentages are evident for J.N. "Ding" Darling N.W.R. (33% decrease in active burrows) and Lake Woodruff N.W.R. (34% increase in active burrows). Interpreted broadly, these results suggest that conditions for tortoises during the last decade have improved at Lake Woodruff N.W.R., degenerated at J.N. "Ding" Darling N.W.R., and remained similar elsewhere. The seeming lack of change in conditions on some federal lands must be viewed with caution, however, because even slight demographic changes in long lived species can be important to maintenance of populations (Van Horne, 1983).

If conditions for tortoises have not changed much at a particular location, we would expect the size distribution of tortoises there also to have changed little, relative to those of tortoises living where conditions have changed substantially. In the case of federal lands in Florida, we would predict that the size distributions of active plus inactive burrows (the burrows that can be used by tortoises) at Chassahowitzka N.W.R., Everglades N.P., and Fort Matanzas N.M. should be more alike between the 1978-79 and 1987-88 surveys than the distributions at J.N. "Ding" Darling N.W.R. and Lake Woodruff N.W.R. If the decline of tortoises at J.N. "Ding" Darling N.W.R. were real, and were caused by, say, decreased recruitment of small individuals, it would be accompanied by a shift in the size distribution of burrows toward the larger categories. Likewise, if the increase in tortoises at Lake Woodruff N.W.R. were real, and were caused by increased recruitment of small tortoises, it would be accompanied by a shift in the size distribution of burrows toward the smaller categories. We compared size distributions of tortoises on the four federal lands for which requisite data were available by dividing the widths of active plus inactive burrows in each of the eight sets of data into eight categories (Table 3). The choice of categories was dictated by the way in which Logan (1979) presented his data. Kolmogorov-Smirnov Tests show that only the two size distributions of burrows at Everglades N.P. differ significantly ($p<0.05$), contrary to our expectations.

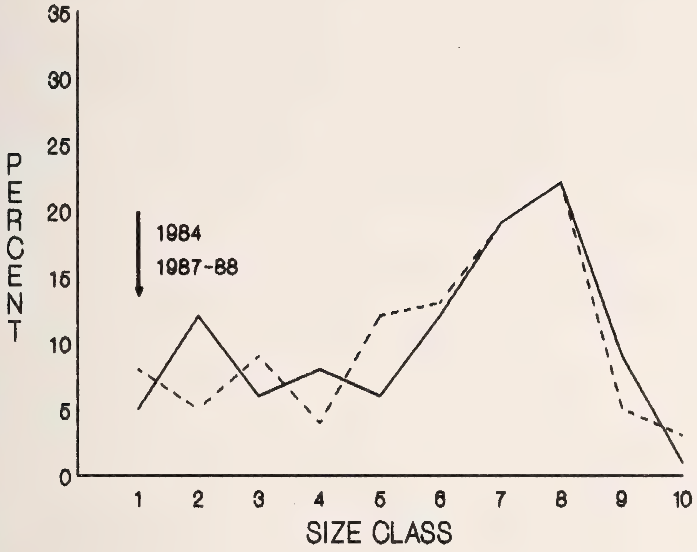
We suspected that certain shortcomings of the data provided to us by Logan (1979) may have reduced the utility of the comparisons of size distributions that we had made. In particular, we noted that three of the four data sets were gathered during transect surveys, allowing for the distinct possibility that frequencies of size classes of burrows estimated from samples were not close to the real frequencies in a population. The earlier data gathered at J.N. "Ding" Darling N.W.R. were done by complete survey, however, so are less suspect.

TABLE 3. Estimated size distributions of active + inactive burrows for four federal lands in Florida surveyed by Logan (1978-79: A) and by us (1987-88: B). Asterisks indicate data obtained by transect surveys.

Location		Percent of Burrows in Size Classes (Upper Limit)							
		5	10	15	20	25	30	35	>35 (cm)
Chassahowitzka N.W.R.	(A)	0	3	9	7	25	38	18	0*
	(B)	0	0	5	10	21	33	23	8*
Everglades N.P.	(A)	0	0	0	4	54	38	4	0*
	(B)	2	7	9	4	19	19	29	11*
Fort Matanzas N.M.	(A)	0	0	0	16	10	45	29	0*
	(B)	0	3	4	11	19	23	25	15*
J.N. "Ding" Darling N.W.R.	(A)	1	1	4	9	22	31	21	11
	(B)	0	2	4	11	32	20	19	12

Logan (1979) lists width measurements individually for burrows at J.N. "Ding" Darling, allowing a reliable size distribution to be constructed. As well, excellent data are available on widths of tortoise burrows at Everglades N.P. in the early 1980s (Kushlan and Mazzotti, 1984). Kushlan and Mazzotti (1984) measured widths, below the mouth at the point the burrow narrowed, of 73 burrows located on a permanent study plot of 1.45 ha. We were able, therefore, to compare size distributions for a location where the tortoise population appears, from data documenting a decrease in the relative number of active burrows, to be in decline (J.N. "Ding" Darling N.W.R.) and another where the tortoise population appears, from the same sort of evidence, to be relatively stable (Everglades N.P.).

The size distributions of tortoise burrows at Everglades N.P. described by Kushlan and Mazzotti (1984) and us (Fig. 1) are significantly different (Kolmogorov-Smirnov Test, $p<0.05$), as are the distributions at J.N. "Ding" Darling N.W.R. described by Logan (1979) and us (Fig. 2). To make these comparisons, we divided the widths of active plus inactive burrows in each of the four sets of data into ten equal-sized categories, for burrows ranging from 4.5 cm to 44.5 cm (Kushlan and Mazzotti 1984). The difference between dis-



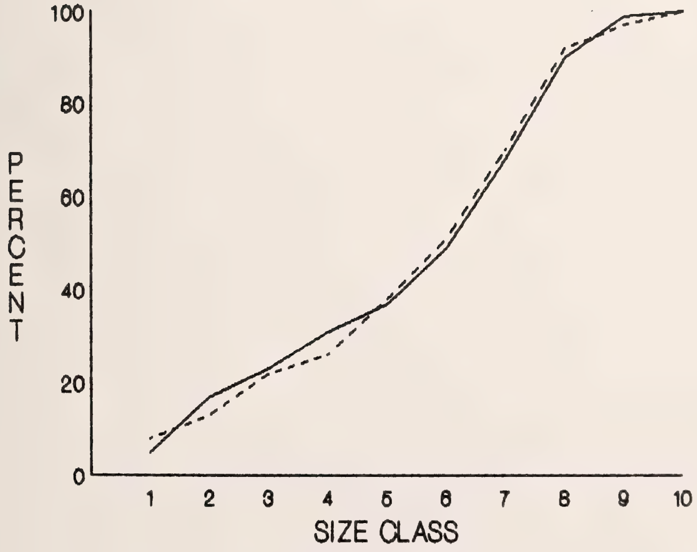


FIG. 1 Size distribution of active plus inactive burrows at Everglades N.P. The lower graph is a cumulative distribution. Solid lines are Kushlan and Mazzotti's (1984) data, dashed lines are our data. Arrow indicates the size category containing the smallest active burrow found during both surveys.

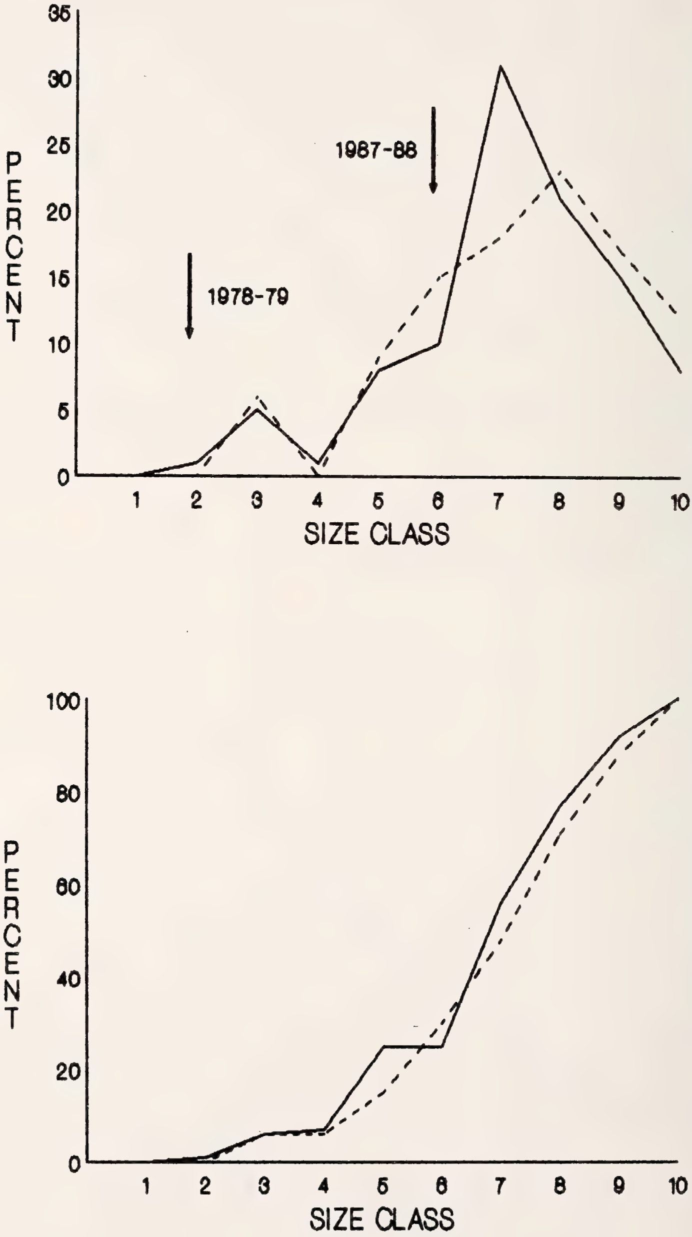


FIG. 2. Size distribution of active plus inactive burrows at J.N. "Ding" Darling N.W.R. The lower graph is a cumulative distribution. Solid lines are Logan's (1979) data, dashed lines are our data. Arrows indicate the size category containing the smallest active burrow found during each survey.

tributions at Everglades N.P. results largely from an offsetting of peaks in sizes of small burrows, a result not unexpected for an organism with periodic bursts of reproductive success (Auffenberg and Iverson, 1979). Some of the very small burrows were active in both years at Everglades N.P., and half of the cumulative distribution of burrow widths was reached at the same size category in both years. On the other hand, the difference between distributions at J.N. "Ding" Darling N.W.R. results mostly from a shifting of burrows to larger size categories in the later distribution: half of the cumulative distribution of burrow widths was reached one size category larger in 1987-88 than in 1978-79. No very small burrows were determined to be active at J.N. "Ding" Darling N.W.R. in the later survey, although some were in the earlier survey. All of these temporal differences between size distributions of the population at J.N. "Ding" Darling N.W.R. point to lack of recruitment of small individuals. Mushinsky and McCoy (1992) suggest that responses of tortoises to vegetation structure may be responsible, in large part, for the demographic trends we have documented on these two federal lands.

DISCUSSION—Our intent was to document any changes in gopher tortoise abundance on federal lands in Florida that have occurred in the last decade, and to suggest causes of those changes. We supposed that the relatively large number of populations would allow us to draw strong general conclusions about the management practices likely to minimize the adverse effects of isolation, if any, on tortoise populations. We could not make most of the necessary comparisons, however, largely for want of data. In fact, we were able to compare estimates of population sizes and of size profiles for only two populations. Some of the tortoise populations were too small to document changes reliably, while others were too large. For intermediate populations, we often could not locate appropriate data to make the demographic comparisons necessary to judge their well-being. Such comparisons are especially important for long-lived species such as the gopher tortoise, because population size can appear quite stable even when a population is in decline (see Van Horne, 1983). Relatively subtle changes in percentage of small active burrows, (as noted for some of the federal lands) may provide an early indication that a tortoise population is in decline and allow measures to be taken to deal with the cause of the decline in a timely fashion.

In spite of the difficulty we encountered in making temporal comparisons of gopher tortoise populations, two important conclusions for future management plans (see Auffenberg and Franz, 1982; Diemer, 1986) emerge from our results. First, even gopher tortoise populations on reserves can decline in well-being. Protection of the land per se does not necessarily assure the well-being of resident organisms. We sense in our reading of the literature that this seemingly-obvious statement tends to be overlooked when current and future needs of the gopher tortoise are discussed. The need for management of populations on reserves leads to our second conclusion, which is that reserves need to be monitored. "Continuous inventory" (sensu Dawkins,

1971) of reserves should be employed to monitor both the resident tortoise population and its habitat. A gopher tortoise population on a reserve, in our estimation, is not a suitable candidate for laissez faire management practices; and we suggest that its demographic health needs to be assessed at intervals to forestall decline. Furthermore, the collection of demographic data should be done in a manner that permits meaningful comparisons within and among populations through relatively long periods of time. These comparisons are necessary to document, and to understand the causes of, temporal and geographical variation in the response of tortoise populations to changes in their environments. Such understanding is essential to prevent the decline of tortoises on reserves. Data not suited to making comparisons, no matter how voluminous and conscientiously collected they may be, do not foster the necessary understanding.

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LITERATURE CITED

Alford, R. A. 1980. Population structure of *Gopherus polyphemus* in northern Florida. J. Herpetol. 14: 177-182.

Auffenberg, W., and R. Franz. 1982. The status and distribution of the gopher tortoise *(Gopherus polyphemus)*. Pp. 95-126. *In* Bury, R. B. (ed.). North American tortoises: conservation and ecology. U.S. Fish and Wildl. Serv. Wildl. Res. Rep. 12.

________, and J. B. Iverson. 1979. Demography of terrestrial turtles. Pp. 541-569. *In* Harless, M., and H. Morlock (eds.). Turtles: perspectives and research. John Wiley and Sons, New York, N.Y.

Burke, R. 1989. Burrow-to-tortoise conversion factors: comparison of three gopher tortoise survey techniques. Herp. Rev. 20: 92-94.

Burnham, K. P., and D. R. Anderson. 1984. The need for distance data in transect counts. J. Wildl. Manage. 48: 1248-1254.

________, D. R. Anderson, and J. L. Laake. 1985. Efficiency and bias in strip and line transect sampling. J. Wildl. Manage. 49: 1012-1018.

Dawkins, H. 1971. Techniques for long-term diagnosis and prediction in forest communities. Pp. 33-44. *In* Duffey, E., and A. S. Watt (eds.). The scientific management of animal and plant communities for conservation. Blackwell Scientific Publishers, Oxford, U.K.

Diemer, J. E. 1986. The ecology and management of the gopher tortoise in the southeastern United States. Herpetologica 42:125-133.

Eberhardt, L.L. 1988. Testing hypotheses about populations. J. Wildl. Manage. 52: 50-56.

Kuhslan, J. A., and F. J. Mazzotti. 1984. Environmental effects on a coastal population of gopher tortoises. J. Herpetol. 18:231-239.

Logan, T. 1979. Survey of gopher tortoise *(Gopherus polyphemus)* populations on federal lands in Florida. Florida Game and Fresh Water Fish Commission, Gainesville, Fl. 104 pp. Pers. Commun.

Martin, P. L., and J. N. Layne. 1987. Relationship of gopher tortoise body size to burrow size in a southcentral Florida population. Florida Scien. 50:264-267.

Mushinsky, H. R. and E. D. McCoy. 1992. Density of gopher tortoises *(Gopherus polyphemus)* in relation to habitat structure, on twenty State and federal lands in Florida. Pp. 000-000. *In* Bury, R. B., and D. Germano (eds.). North American Tortoises: Recent Research and Opportunities into the Twenty-first Century. U.S. Fish and Wildl. Serv. Res. Rep. No. 000.

Van Horne, B. 1983. Density as misleading indicator of habitat quality. J. Wildl. Manage. 47:893-901.

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REPORT OF A CAVE FAUNA KILL AT PEACOCK SPRINGS CAVE SYSTEM, SUWANNEE COUNTY, FLORIDA.—

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Abstract: *A cave fauna kill was observed within the aquatic cave system at Peacock Springs, Suwannee County, Florida following inundation by flood waters of the Suwannee River early in 1991. Populations of the pallid cave crayfish* (Procambarus pallidus), *the yellow bullhead* (Ictalurus natalis), *the American eel* (Anguilla rostrata), *and the Asiatic clam* (Corbicula fluminea) *were affected. Following the kill, an oligochaete worm, family Tubificidae, colonized the cave with a mean density of 744 individuals per m^2.*

Aquatic cave systems associated with the Floridan aquifer support a number of troglobitic (obligatory cave-dwelling) and troglophilic (facultative cave-dwelling) species. However, ecological data on these animals are scarce, primarily because of difficulties associated with working in the aquatic cave environment (Relyea and Sutton, 1973).

The pallid cave crayfish *Procambarus pallidus* is known to inhabit numerous caves along the upper Suwannee River, including the Peacock Springs cave system (Franz and Lee, 1982). The Peacock Springs cave system, located in Suwannee County, Florida (latitude 30°07'10" N, longitude 83°10'02"W) consists of over 7000 m of known passage, all of which is underwater. Depths vary from 3 m to over 60 m. Throughout most of the year, water from the Floridan aquifer flows through the cave system. During periods of normal flow, currents are slight and in some areas undetectable. Water temperatures are stable, ranging from 21-22°C. Following heavy rains, however, water from the Suwannee River flows into the cave system, temporarily altering current direction and rate, water quality, and water temperature.

In the fall of 1990, divers established 8 transects, each 100 m long by 4 m wide, at locations throughout the cave (Fig. 1). Since *P. pallidus* roams in the open on the cave floor, crayfish on transects could be counted visually. A kill occurred while the cave was inundated by Suwannee River flood water. Pre-kill population counts were collected between 21 October 1990 and 2 February 1991, prior to Suwannee River flood water inundation on 2 February 1991. Following inundation, diving was suspended due to low visibility associated with the flood waters. Post-kill population counts were collected after 25 April 1991 when visibility improved. Counts are summarized in Table 1.

In addition to the dead crayfish tabulated for each transect, crayfish remains were found scattered throughout the cave system. The bodies of 3 troglophilic yellow bullhead *Ictalurus natalis* were found. No living *I. natalis* were sighted immediately following the kill, although it was common to see 10-30 individuals per dive prior to the kill. Similarly, the American eel *Anguilla rostrata* was no longer seen following the kill, although 1-3 individuals per dive were seen prior to the kill. A large population of *Corbicula fluminea*, present near transect 7 in mean densities of 167 per m^2 ($SD=191/m^2$, $n=7$) prior to the kill (Streever, 1992), suffered 100% mortality.

Although crayfish mortality along the transects was 100%, live crayfish were present in passages adjacent to the transects; thus, while crayfish mortality was high it was not 100% throughout the cave system. Also, the large ratio of pre-kill crayfish present along transects to post-kill crayfish bodies found along transects, particularly on transects 7 and 8, suggests that some of the crayfish may have been flushed away from the transects by high currents and redeposited deeper in the cave system. Although no data are available for the flushing tolerance of *P. pallidus*, flushing tolerances for three Florida troglobitic crayfish—*Procambarus horsti*, *Procambarus orcinus*, and *Cambarus cryptodytes*—are between 28.6 and 41.2 cm/sec (Caine, 1978). Based on obvious changes in the cave's sediment and the presence of whirlpools at cave entrances during flood water inundation, flushing tolerances may have been exceeded.

TABLE. 1. Procambarus pallidus transects in Peacock Springs cave system before and after a major cave fauna kill following inundation by Suwannee River flood waters. Post-kill numbers are the result of a single count.

Transect number	Number of crayfish before kill	Number of crayfish after kill	Number of crayfish bodies after kill
1	1 (SD=1, n=3)	0	0
2	6.5 (SD=0.7, n=2)	0	0
3	1.5 (SD=0.7, n=2)	0	0
4	4 (SD=0, n=3)	0	0
5	1 (SD=0, n=4)	0	0
6	6.2 (S D=0.8, n=5)	0	7
7	34.5 (SD=2.7, n=8)	0	0
8	49.5 (SD=7.1, n=8)	0	2

The oligochaete worm, family Tubificidae, appeared in densities of 744 individuals per m^2 ($SD=178$, $n=8$) immediately after the flood waters subsided. Densities were measured by counting worms within a 0.04 m^2 quadrat randomly placed within transect 7. Since some of the worms withdrew into their burrows as divers approached, actual densities were undoubtedly higher than those recorded. All worms collected were immature and could not be classified beyond family. Worms were observed scattered throughout the cave system to distances of over 500 m from cave entrances and at depths exceeding 50 m. High concentrations of Tubificidae are often associated with

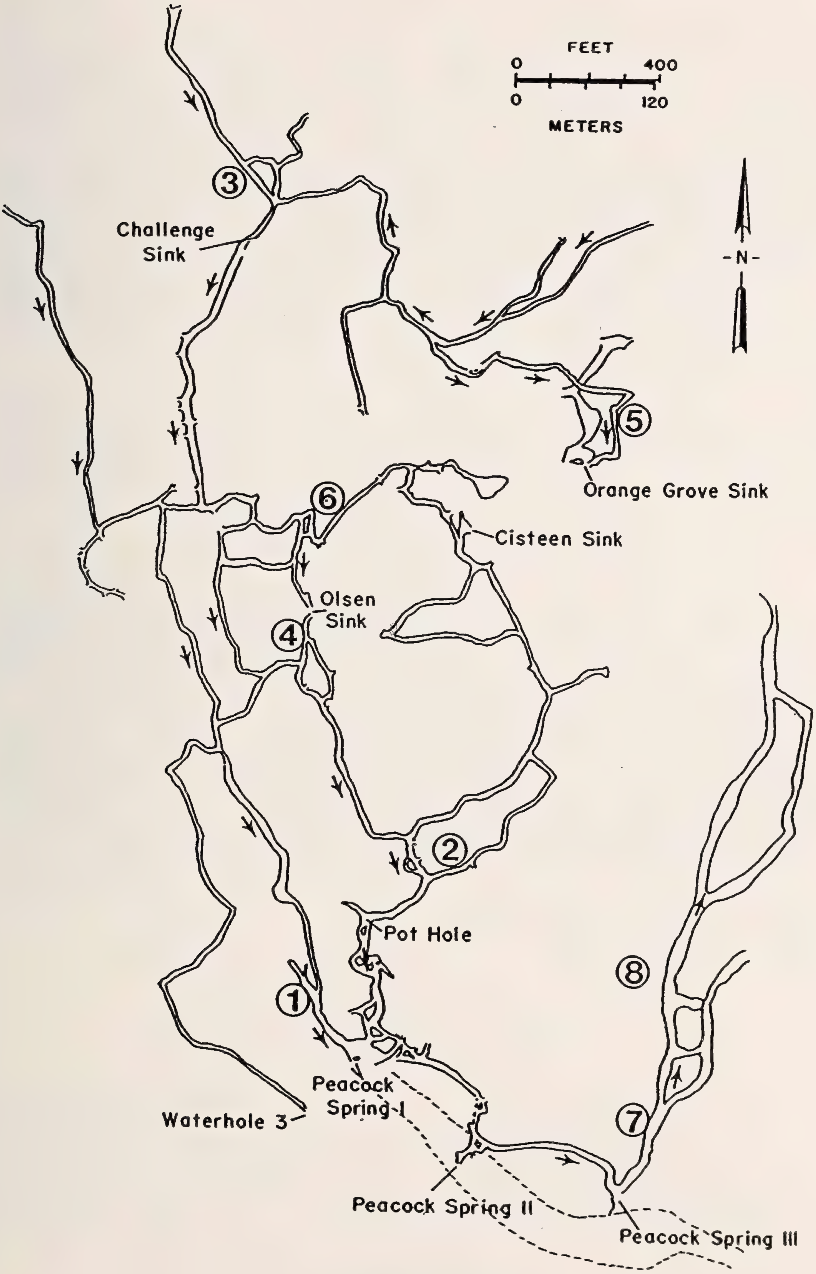

FIG. 1. Peacock Springs cave system, Suwannee County, Florida with arrows indicating direction of normal water flow and numbers indicating permanent transect stations.

organic pollutants (Pennak, 1953), and there is some possibility that pollutants were partly or wholly responsible for the kill. However, personal communications with cave diver Tom Morris (1991) indicate that colonization by oligochaete worms has been observed in other cave systems where no faunal kills occurred.

Despite the apparent cause and effect relationship between river water intrusion into the Peacock Springs cave system and the kill reported here, other cave fauna kills are not always accompanied by flood waters (Morris, 1991). Furthermore, flood waters frequently inundate cave systems along the Suwannee River basin without apparent damage to fauna. It is possible that the kill at the Peacock Springs cave system was not directly related to the intrusion of Suwannee River water.

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LITERATURE CITED

Caine, E. A. 1978. Comparative ecology of epigean and hypogean crayfish (Crustacea: Cambaridae) from Northwestern Florida. The American Midland Naturalist 99 (2):315-329.

Franz, R. and Lee, D. S. 1982. Distribution and evolution of Florida's troglobitic crayfishes. Bull. Florida State Mus. Biol. Sci. 28(3):53-78.

Morris, T. 1991. 2629 N.W. 12th Avenue, Gainesville, Florida. Pers. Commun.

Pennak, R. W. 1953. Freshwater Invertebrates of the United States. The Ronald Press Company, New York. 769 pp.

Relyea, K. and B. Sutton. 1974. Ecological data for a Florida troglobitic crayfish. Florida Scientist 36:234-235.

Streever, W. J. 1992. First record of *Corbicula* clams within flooded cave systems.

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FLORIDA SCIENTIST

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Volume 55 Summer, 1992 Number 3

Biological Sciences

SURVIVAL AND GROWTH OF STEM FRAGMENTS FROM VARIOUS HYDRILLA RACES.

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ABSTRACT: *Fragments from sixteen separate races of hydrilla [*Hydrilla verticillata, *(L.f.) Royle] collected worldwide were evaluated in outside aquaria for ability to survive and grow. Differences were observed between races in their potential to establish and grow from fragments. Total biomass varied approximately sevenfold between the least and most productive races. The difference between the initial fragment and final weights ranged from 14 to 250 fold. Survival varied between 10 and 73%. A significant negative relationship was observed between first root development time and biomass. The number of rooted nodes which developed on stolons was the best single predictor of biomass production. Rates of root development on fragments of the various hydrilla races are criteria that may be useful in predicting the ability of the races to become established. Differences in shoot and root development were observed between races in their responses to applied plant growth regulators.*

THE ability of some submersed aquatic angiosperms such as hydrilla to rapidly infest and colonize new sites is due in part to their capacity to proliferate from stem fragments. The slender fragile stems of these plants, since they are buoyed up and supported by water, are deficient in mechanical tissues and are readily broken by wave action, strong currents, or other disturbance. Almost any detached fragment containing meristematic tissue can regenerate a new individual (Sculthorpe, 1967). These fragments, carried by currents, are capable of being transported great distances. They eventually lose buoyancy, settle to the bottom, become attached and establish new colonies (Smith et al., 1967; Johnson and Bagwell, 1979; Kimbel, 1982; Bowmer et al., 1984).

Langeland and Sutton (1980) observed survival and growth of dioecious Florida hydrilla fragments to be directly related to the number of nodes per fragment. They reported that regrowth ranged from 28%, in one-node fragments under both laboratory conditions and in outside aquaria, to 98% and 100% in five-node fragments under lab or field conditions respectively.

The worldwide distribution of hydrilla is evidence of the ability of the species to tolerate diverse habitats. Hydrilla is a very polymorphic species and identification of numerous isoenzyme phenotypes among the several races of hydrilla collected worldwide is evidence of high genetic variability (Ryan 1989; Verkleij and Pieterse, 1986; Verkleij et al., 1983a,b). We (Steward and Van, 1987; and Steward, 1991) demonstrated that different physiological phenotypes occur within the species. Steward and Van (1987) observed differences in physiological responses to photoperiod and temperature within and between races of different isoenzyme phenotypes. Steward (1991) observed growth responses to different pH values to vary both within as well as between 15 races of hydrilla collected worldwide. Van Vierssen and others (1986) provided additional evidence of species plasticity when they demonstrated that differences in leaf morphology existed between isoenzyme phenotypes. Morphology was altered between and within phenotypes by altering external concentrations of nitrate and bicarbonate. As part of our ongoing studies to gain better understanding of hydrilla's biology, we compared the ability of the various races of hydrilla in the Agricultural Research Service collection at Ft. Lauderdale to survive and to regrow from fragments.

METHODS AND MATERIALS—Aquarium Study. This experiment was conducted over the period 20 June to 12 August 1988 in outdoor concrete aquaria on the grounds of our Ft. Lauderdale laboratory facility. The aquaria were 219 cm long, 77 cm wide and 65 cm deep and of approximately 1000 liters capacity. Natural water, pumped from a dug pond on the facility, was supplied to individual aquaria to provide a complete volume exchange every 12 hours. The quality of the aquifer supplied water was described earlier (Steward,1984) and has not changed. Individual aquaria were subdivided into six compartments by suspending 1 mm mesh fiberglass screening on flat metal bars (3 mm thick 15 mm wide 85 cm long) from the edge of the aquaria. The screening was weighted at the bottom and fit tightly against the sides and bottom to prevent escape and mixing of plant material. Plastic pans, filled with soil, covered the bottom of each compartment and served as substrate for hydrilla fragments to root. The soil was our standard formula of 10% v/v composted cow manure and sterilized commercial nursery mix (Steward and Van 1987). Each compartment received five, three-node fragments cut 10 cm from the apex of uniform stems of individual races of hydrilla. Only one fragment was taken from each stem. Plant material for the experiment was taken from 16 races of hydrilla (Table 1) from cultures of our collection being maintained at the laboratory.

Experimental design—The experiment was conducted as a balanced incomplete block design (cf., plan 11.27; Cochran and Cox 1957, p. 478). Hydrilla races served as treatments, aquaria as blocks and compartments as experimental units. Treatments were replicated six times and were assigned to blocks, as per the plan, but randomly within the aquaria. Blocks (aquaria) were randomly assigned.

Data and sample collection—Measurements were taken of initial lengths of fragments and initial dry weights were estimated from representative samples of fragments. Daily records were made of shoot and root development and of fragment survival. At harvest, the numbers of rooted nodes and shoots were recorded and oven-dry weights (65°C) of new growth were obtained .

Laboratory study—Plant fragments, as previously described, were exposed to various concentrations of plant growth regulators (PGR) to evaluate any effects on the initiation and development of shoots and roots. Fragments were taken from two groups of plants comprised of three races, each of which had, in the aquarium study, exhibited either high (Group A) or low (Group B) rates of root development. These fragments were treated with abscisic acid (ABA) at 10^{-3} and 10^{-2} M concentrations to inhibit (Group A) or indole acetic acid (IAA) at 10^{-7}, 10^{-5}, 10^{-3} and 10^{-2} M, to enhance (Group B) shoot and root development. Fragments were exposed for 35 days (August 16-Sept. 19, 1990) at the higher concentrations, and 36 days (Feb. 1-March 8, 1991) at the lower IAA concentrations. Treatments of 200-ml volume, which were changed weekly, were applied to each of five replicates of five fragments per replicate contained in 14-cm diameter

TABLE 1. Approximate geographical location of various collected races of hydrilla evaluated for fragment survival.

Race	Location		Flower[1]
Alice River, Australia	23 S	145 E	PS
Bangalore, India	13 N	77 E	S
Beijing, China (BJ)	40 N	116 E	PS
Cairn, Queensland, Aust.	17 S	145 E	PS
Chongqing, China (CQ)	29 N	106 E	P
Davie, FL	26 N	80 W	P
Guangzhou, China	23 N	113 E	P
Kunming, China	25 N	102 E	PS
Lake Anne, NC	36 N	79 W	PS
Lily Pons, MD	39 N	77 W	PS
Panama Canal, Panama (PC)	9 N	80 W	S
Penang Island, Malaysia	5 S	100 E	PS
Papua, New Guinea (NG)	6 S	144 E	PS
Potomac River, VA	38 N	77 W	PS
Tainan, Taiwan (TN)	23 N	120 E	PS
Trapp Pond, DL (DL)	38 N	75 W	PS

[1] Dioecious P=pistillate, S=staminate, PS=monoecious

petri dishes with covers. Fragments were exposed to 193 μmol quantam$\bullet^{-2}\bullet$s^{-1} PAR of 16 hours duration provided by 1:1 cool white:Grolux (GTE Sylvania Inc., Danvers, MA 01923) fluorescent tubes. The number of developing shoots and roots was used as response criteria. Experiments were conducted on benches in a temperature controlled laboratory (25±2°C) and a completely randomized design was used.

Statistical analyses were performed using ANOVA, GLM AND REG procedures for personal computers (SAS Institute Inc., Box 8000, Cary, NC 27511).

RESULTS—*Aquarium Study*—We determined that there were differences between races in their potential to establish and grow from fragments. All races successfully established new growth from the initial three-node fragments. The estimated combined oven-dry starting weight of fragments, ranging from 15 to 52 mg, produced from 0.7 to 4.9 g dry weight biomass in 45 days (Table 2A). Total biomass varied approximately seven-fold between the least and most productive races. The growth coefficients, as determined by the ratios of initial and final harvest weights, ranged from 14 to 250 between races (Table 2B). The Beijing and Tainan races were more productive than 13 of the 16 races. The number of fragments with evidence of regrowth, in the form of shoot or root development, represented a 10% (Kunming) to 73% (Papua) survival rate (Table 2C). Correlation between shoot and root development on initial fragments was highly significant at $r = 0.99$, $p = 0.0001$. The number of rooted nodes, which developed on stolons of the various races in this present study, ranged from four on the Chongqing to 28 on the Beijing race (Table 2D). The development of shoots on rooted nodes ranged from nine on the Kunming race to 72 on the Beijing race (Table 2E). There was a significant correlation between the number of rooted nodes and number of shoots which developed on stolons ($r=0.95$, $p=0.0001$). As would be expected, correlations between biomass production and numbers of rooted nodes or shoots were nearly as strong and identical ($r=0.89$, $p=0.0001$).

TABLE 2. Growth of fragments from the various races of hydrilla evaluated for fragment survival.[1]

Race	A Dry Wt. Biomass (g)	B Growth Coefficient	C Fragments Regrowing (No.)	D Rooted Nodes (No.)	E Shoots (No.)	F First Shoot (Days)	G First Root (Days)
Papua	4.9 a	117 bcd	3.7 a	26 ab	61 ab	7 a	8 d
Beijing	4.8 a	250 a	2.7 abc	28 a	72 a	8 a	8 d
Cairn	4.7 a	41 de	2.0 cdef	24 abc	46 abcde	8 a	10 d
Tainan	4.6 ab	241 a	2.3 bcd	27 a	55 abc	7 a	9 cd
Bangalore	4.3 ab	189 ab	3.3 ab	25 abc	49 abcd	6 a	9 cd
Penang I.	2.8 abc	54 de	1.2 efg	15 abcd	24 def	9 a	10 cd
Davie	2.4 bc	47 de	2.2 cde	7 d	19 def	9 a	16 bc
Guangzhou	1.8 c	41 de	2.7 abc	16 abcd	39 bcdef	9 a	12 cd
Alice R.	1.7 c	39 e	2.5 bc	14 abcd	32 bcdef	7 a	12 cd
Lilypons	1.1 c	75 cde	2.0 cdef	11 cd	29 cdef	7 a	11 cd
Kunming	1.1 c	39 e	0.5 g	4 d	9 f	11 a	11 cd
L. Anne	1.0 c	33 e	1.3 defg	12 bcd	28 cdef	10 a	11 cd
Potomac	0.8 c	25 e	1.2 efg	7 d	18 ef	7 a	10 cd
Panama	0.7 c	14 e	1.2 efg	4 d	10 f	13 a	28 ab
Chongqing	0.7 c	17 e	1.3 defg	4 d	12 f	7 a	25 a
Trapp Pond	0.7 c	34 e	1.0 fg	7 d	20 def	6 a	22 ab

[1] Means within columns not different when followed by the same letter using Waller-Duncan Test KRATIO=100.

There was an inverse and identical relationship ($r=-0.26$, $p=0.015$) between development time of the first shoot (Table 2F) and number of shoots (Table 2E) or number of rooted nodes (Table 2D) which developed. The correlation was slightly stronger between development time of the first root (Table 2G) and number of rooted nodes ($r=-0.46$, $p=0.0001$) or number of shoots ($r=-0.45$, $p=0.0001$). Development of shoots always preceded root development and the lag time ranged from 0.1 days in the Beijing race to nearly 18 days in the Chongqing race (compare Table 2F with 2G). The correlation between development time of the first shoot and biomass (Table 2A) was $r=-0.23$, $p=0.03$, and between development time of the first root and biomass was $r=-0.44$, $p=0.0001$. Early root formation appeared to have promoted increased biomass production. Additional support for this conclusion was provided statistically by using the SAS stepwise regression procedure on the regression of biomass on the variables: (a) number of rooted nodes, (b) shoot numbers, (c) development time of first root and (d) development time of the first shoot. Results of analyses indicated that the number of rooted nodes was the best single variable model with a coefficient of determination (r^2) of 0.76, and the best two variable model included shoot numbers, which increased r^2 to 0.78. No other variables met model entry-level requirements ($p=0.15$). These results indicate that the number of rooted nodes that developed on stolons was the best single predictor of biomass production, accounting for 76% of total variability.

Laboratory Study—Group A plants–Beijing (BJ), Papua (NG) and Tainan (TN) - had exhibited high average production rates of roots (3.1 rooted nodes/day) and shoots (7.4/day) in the aquarium study (Table 2). Except for the TN race, shoot and root initiation were suppressed by laboratory ABA treatments in these races (Table 3). These results confirm those of Van and others (1978) who reported growth inhibition of Florida hydrilla by ABA under both 10- and 16-hr photoperiods, along with promotion of tuber production under long days. These effects of ABA are examples of but a few of many of the known regulatory activities: on dormancy, growth rate, flower initiation, fruit growth, tuberization, abscission and senescence (Leopold and Kriedemann, 1975; Zeevaart and Creelman, 1988).

Group B plants–Chongqing (CQ), Panama (PC) and Trapp Pond (DL)–had exhibited low rates of shoot, root and biomass production in the aquarium study (Table 2). In this study, shoot and root production were promoted by IAA only in the DL race, which is evidence of possible low endogenous levels (Table 3). Shoot and root production were reduced in the PC race at 10^{-3} and 10^{-2} M IAA but not at the lower concentrations. IAA normally promotes growth but has been reported to inhibit at high concentrations (Burg and Burg, 1966, 1968; Leopold and Kriedemann, 1975, p. 110). Inanc (1960) found a concentration of 10^{-8} M IAA to be optimal in promoting both root initiation and root elongation in *Elodea canadensis* L.C. Rich. Van (1978) obtained increased shoot and root production in Florida hydrilla with 1 mM IAA treatments. The observation in the aquarium study that shoot growth on fragments always preceded root development may be related to increased IAA levels because the usual sites of IAA formation in vascular plants are meristems and enlarging tissues (Leopold and Kriedemann, 1975, p. 120).

TABLE 3. Effects of ABA or IAA treatments on development of shoots and roots on fragments of selected hydrilla races after 36 days[1].

Substance, M	Characteristcs					
	Shoots (No.)			Roots(No.)		
ABA	BJ	NG	TN	BJ	NG	TN
0	4 a	2 a	1 n[2]	4 a	2 a	1 n
10^{-3}	0 b	0 b	2 n	0 b	0 b	1 n
10^{-2}	0 b	0 b	0 n	0 b	0 b	0 n
IAA	PC	DL	CQ	PC	DL	CQ
0	4 a	2 n	2 n	4 a	1 n	2 n
10^{-3}	2 b	2 n	3 n	2 b	1 n	2 n
10^{-2}	2 b	3 n	3 n	2 b	3 n	3 n
0	2 n	1 b	3 n	2 n	0.2 c	2 n
10^{-7}	3 n	2 ab	3 n	3 n	1.4 b	2 n
10^{-5}	2 n	3 a	4 n	2 n	2.0 a	3 n

[1] Means within columns not different if followed by the same letter using Waller-Duncan Test, KRATIO=100.
[2] n=not significantly different.

DISCUSSION—Once established, hydrilla colonizes new area by extending runners or stolons along the bottom substrate. Shoots and roots, which develop at the nodes of these stolons, provide support and nourishment to this new growth which, in turn, promotes continued colony expansion. The number of rooted nodes that developed on stolons of the various races determined most precisely their growth in biomass. The rate of root development was directly related to biomass increase. It appeared that early root development provided additional growth time, which allowed for greater biomass production. There was weak evidence that rate of root production may be related to levels of endogenous IAA. The rates of root development on fragments of the various hydrilla races are criteria that may be useful in predicting the ability of the races to become established and in predicting the relative rate of colonization of new areas of infestation. Five of 16 races evaluated in this study had significantly higher rates of root development than those races presently established in the U.S. These five foreign races, if they were accidently introduced, have potential for causing far more serious problems than already exist. Growth inhibitors such as ABA may have utility in preventing or retarding the spread of hydrilla into new areas and further research seems warranted.

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LITERATURE CITED

Bowmer, K. H., D. S. Mitchell, and D. L. Short. 1984. Biology of *Elodea canadensis* Michx. and its management in Australian irrigation systems. Aquat. Bot. 18:231-38.

Burg, S. P. and E. A. Burg. 1966. The interaction between auxin and ethylene and its role in plant growth. Proc. Natl. Acad. Sci. 55: 262-69.

________ and E. A. Burg. 1968. Ethylene formation in pea seedlings: Its relation to the inhibition of bud growth caused by indoleacitc acid. Plant Physiol., 43:1069-74.

Cochran, W. B. and G. M Cox. 1957. Experimental Designs. John Wiley and Sons, New York, NY. 2nd ed. 616 pp.

Inanc, N. 1960. Investigations upon the physiological and the histological changes occurring in the structures of certain well adapted and least adapted submerged aquatic plants under the action of growth regulating compounds. *Istanb. Univ. Fen Fak. Mecm.*, ser. B,25,93-144. *Cited in:* Sculthorpe, C. D. 1967. Biology of Aquatic Vascular Plants. St. Martin's Press. New York, NY p. 156.

Johnson, R. E. and M. R. Bagwell. 1979. Effects of mechanical cutting on submersed vegetation in a Louisiana lake. J. Aquat. Plant Manage. 17:54-57.

Kimbel, J. C. 1982. Factors influencing potential intralake colonization by *Myriophyllum spicatum* L. Aquat. Bot. 14:295-307.

Langeland, K. A. and D. L. Sutton. 1980. Regrowth of hydrilla from axillary buds. J. Aquat. Plant Manage. 18:27-29.

Leopold, A. C. and P. E. Kriedemann. 1975. Plant Growth and Development. McGraw-Hill Book Company, New York, NY. 545 pp.

Ryan, F. J. 1989. Isoenzymic variability in monoecious Hydrilla in the United States. J. Aquat. Plant Manage. 27:10-15.

Sculthorpe, C. D. 1967. Biology of Aquatic Vascular Plants. St. Martin's Press. New York. 610 pp.

Smith, G. E., T. F. Hall, Jr., and R. A. Stanley. 1967. Eurasian watermilfoil in the Tennesee Valley. Weeds 15(2):95-98.

Steward, K. K. 1984. Growth of hydrilla *(Hydrilla verticillata)* in hydrosoils of different composition. Weed Sci. 32(3):371-75.

________ AND T. K. VAN. 1987. Comparative studies of monoecious and dioecious hydrilla *(Hydrilla verticillata)* biotypes. Weed Sci. 35:204-10.

________. 1991. Growth of various hydrilla races in water of differing pH. Florida Scient. 54(2): 117-25.

VAN, T. K. 1978. Physiology and control of hydrilla tuber production. Pp. 40-51. In: Annual report to the Florida Dept. of Natural Resources. Agronomy Dept., Inst. of Food and Agric. Sci., Univ. Florida, Gainesville, FL. 32611.

, W. T. HALLER, AND G. BOWES. 1978. Some aspects of the competitive biology of hydrilla. Pp. 117-26. *In:* Proc. EWRS 5th Int. Symp. Aquat. Weeds, Amsterdam.

VAN VIERSSEN, W., A. W. BREUKELAAR, AND H. W. PEPPELENBROS. 1986. A comparison of some morphological characteristics of four hydrilla strains under different environmental conditions. *In*: Pp. 369-74. Proc. EWRS/AAB 7th Symp. on Aquatic Weeds.

VERKLEIJ, J. A. C. AND A. H. PIETERSE. 1986. Identification of *Hydrilla verticillata* (L.f.) Royle strains by means of isoenzyme patterns. Proc. *In:* Pp. 381-88. EWRS/AAB 7th Symp. Aquatic Weeds.

________, A. H. PIETERSE, G. J. T. HORNEMAN, AND M. TORENBEEK. 1983a. A comparative study of the morphology and isoenzyme patterns of *Hydrilla verticillata* (L.f.) Royle. Aquat. Bot. 17:43-59.

________, A. H. PIETERSE, H. P. M. STAPHORST, AND K. K. STEWARD. 1983b. Identification of two different genotypes of Hydrilla verticillata (L.F.) Royle in the USA by means of isoenzyme studies. *In:* Proc. Int. Symp. Aquat. Macrophytes. Nijmegen, The Netherlands. Pp. 251-61.

ZEEVAART, J. A. D. AND R. A. CREELAMAN. 1988. Metabolism and physiology of absicisic acid. Ann. Rev. Plant Physiol. Plant Mol. Biol. 39:439-73.

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REVIEW

Eugene Garfield, *Journalology, KeyWords Plus^{TM}, and Other Essays*, (Volume 13 of *Essays of an Information Scientist*),
ISI Press, 3501 Market Street, Philadelphia,1991., Pp. xvi + 497. Price: $35.

THE breadth and utility of the author's essays remain one of the remarkable features of this series. What may not have been emphasized in reviews of previous volumes is that some essays serve as useful introductions to reprints of articles the majority of us would likely never read, much to our loss. Essay 3, "Stephen P. Lock on 'Journalology'," for example, precedes an interesting reprint, which includes the suggestion of a retiring editor that "we should shred these [non-conforming] manuscripts and tell the authors to provide us with what we want." Other favorite essays are concerned with C. P. Snow of "The Two Cultures", the impact of fraudulent research (readers catch on fast, and it shows up in citations), "Animal Rights and Wrongs," dangers of alternative medicine, strategies for promoting scientific creativity, and cockroaches. Still other essays are concerned with technical aspects, including most-cited publications, backgrounds of Nobel laureates, citation errors and controlling them, and how journals are picked for inclusion in *Current Contents*®. As always, the author's essays are informative, interesting, well documented, well considered, and considerate.—

D. F. Martin, University of South Florida, Tampa.

THE VEGETATION OF BLOWING ROCKS PRESERVE, JUPITER ISLAND, FLORIDA

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Abstract: *The hydrology, geology, history and vegetation of the Blowing Rocks Preserve is described and the natural plant communities mapped and characterized. The vascular flora of the Preserve consists of 233 species representing 75 families. At least 13 plant species that are endangered, threatened, rare, commercially exploited, or species of special concern were found within the Preserve and at least four species of sea turtles (green, loggerhead, hawksbill, and leatherback) nest on the northern beach.*

Blowing Rocks Preserve, located in Martin County, occupies a 113 acre tract of barrier island on southern Jupiter Island. The Preserve is bounded by the Atlantic Ocean on the east, the Intracoastal Waterway to the west and private homesteads to the north and south. Access to the Preserve is provided by State Road 707 from the mainland through the towns of Jupiter and Hobe Sound.

The most striking feature of the Preserve is the ancient Anastasia limestone outcroppings that formed as a submerged bar during the Pamlico epoch. The bar is perforated by tubular solution holes and cavities through which water spouts during heavy storm surges, hence the name "Blowing Rocks". Similar limestone formations occur along the beaches between Titusville and Palm Beach, but most are covered with sand.

History—The earliest known residents recorded in the area were believed to be the Jaega Indians, "cousins" of the Ais. Recovered pottery and artifacts found along the coast in this area show occupation as early as 500 B.C. (DuBois, 1957). They occupied only three villages in and near Jupiter Island and owe their place in history largely to the fact that they greeted Jonathan Dickinson when he was shipwrecked near Jupiter Inlet in 1696 (Tebeau, 1971). Jonathan Dickinson, his family and other members of their party, finally made their way north through Indian territory to St. Augustine. Later, he wrote a vivid account of his encounters with the native people and their survival. The early editions of Dickinson's journal were published sixteen times between 1699 and 1869, and provide us with one of the earliest and best accounts of southeast Florida (Andrews, 1981). All of Jupiter Island, as well as a vast acreage on the mainland, were once part of the Gomez Grant, a gift to Ensebio M. Gomez for his public service rendered to the government of Spain in 1815.

During the period of 1833 to 1837, John Lee Williams explored and mapped a large part of the southeast coast of Florida and wrote "Jupiter or

Gomez Island…is twenty-five miles long and from half a mile to two miles wide. The eastern side presents a beach sloping off half a mile to low water mark. The ridge of sand hills is high; behind this is a space covered with small oaks and palmettos, while the western side terminates in hammocks, and where the island throws projections into the Hobe Sound the hammocks are of such extent that they might form small farms of excellent land. This side of the island is rocky near the shore. Four miles from the south end, several fruit trees still remain that were planted long since; among these are coconuts, oranges, limes, and plums. Several old fields indicate former settlements. Several dangerous reefs of rocks lie in front of the island." (Williams, 1837).

The first European settlers came to this area in 1842 because of the Armed Occupation Act passed by Congress. This act entitled 160 acres of land in Florida (anywhere south of Palatka) to any settler who could reside on the land for seven years and clear five acres for cultivation. The Indian River Colony settled the area from near Sebastian to Fort Jupiter. However, because of the threat of Indian attack and faring poorly from an economic standpoint, they finally gave up in 1849 in their seventh year of occupation (The Martin County Historical Society, 1975).

In 1855, the historic lighthouse near the south end of the island was built, but it was not until 1881 that Charles Jackson was credited with being the first permanent resident of Jupiter Island. In 1884, James Henshall authored a book about camping and cruising in Florida. His account of Jupiter Island is as follows: "The west shore is a range of high barren sand hills, with a number of long points projecting into the sound, while the east shore (Jupiter Island) is a continuous narrow hammock of great richness, standing well above the water, and underlaid by a ledge of coralline rock. This hamak is known as the Gomez Grant, being one of the old Spanish grants that have been so detrimental to the settlement of east Florida." (Henshall, 1884). He was followed by James A. Armour in 1886, who settled on the south end of the island. At about this time, the Indian River Pineapple and Coconut Grove Association of Florida was formed by a group of Englishmen, mainly as an investment in the future growth of pineapples. In 1892, a group of businessmen from Yorkshire, England purchased the island and formed the Indian River Association, Ltd. However, three years later, in January 1895, the "Big Freeze" hit the area and citrus, pineapples, and investments toppled.

Although first platted in 1885 by the Indian River Pineapple and Coconut Association, it was not until 1913 that a road extending north along the ocean on Jupiter Island was funded (Ziemba, 1968). The primary dune along the ocean was flattened, perhaps even filled in places, and thus old State Road A1A came into existence. However, in the early 1950's, after the 1948 hurricane and the beach erosion it caused on the southern end of the island, the road was rerouted through the middle of the Preserve. This change in the State Road 707 alignment can be noted in the "S" turn north of the Preserve property (R. VandeWeghe, 1989). Along the existing path on the top of the dune, one can still see the old limerock and asphalt that remains from the first road, which was still used by local traffic into the early 1960's (Lund, 1988). However, now it is slowly being revegetated by coastal plants and, in places, completely closed off to foot traffic.

In 1911, the old bridge from Jupiter Island to the town of Hobe Sound was constructed and with it, a road was brought part way down the island. The first Australian pines along Beach Road were planted around 1916 by Titus and Anna Hart, who owned many tracts of land, both on Jupiter Island and on the mainland. Married in 1904, there were only three families on the island when the Harts settled. Their supplies came by boat twice a year (First National Bank & Trust Company of Stuart, 1973).

In the 1930's, several areas west of State Road 707 were impacted by the early dredging of the Intracoastal Waterway. Spoil was pumped onto the island in a slurry and allowed to settle out from the point of discharge. This had an adverse effect on the plant communities by increasing the topographic relief and also by changing the salinity of the soil. The property underwent further changes to reduce the local mosquito population by digging ditches through the area so that *Gambusia* (mosquito fish) could feed on the mosquito larvae. Alongside of these ditches, the spoil was piled on the landscape. It was felt that most of this work on the mosquito ditches was initiated in 1952; however, maintenance work has been conducted on a regular basis over the years as improvements warranted, i.e., culverts to the Indian River instead of an open ditch in 1972 (L. Scherer, 1988).

Purchased by residents of Jupiter Island to protect the rock outcroppings, the initial tract that is now Blowing Rocks Preserve was acquired on April 8, 1969. It was not until 1978 and 1979 that additional properties (about 24 acres) to the north were acquired (Lund, 1979).

Topography—In general, the Preserve typifies a characteristic barrier island profile (Fig. 1). Rising steeply from a narrow beach, a primary dune buffers the higher secondary dune to the west. Elevations of the primary dune range from 10-18 feet above msl and was flattened in the early 20's for construction of State Road A1A. Just west of the old roadway in the northern half of the preserve rises a more prominent secondary dune covered with dense hammock vegetation. Elevations of the secondary dune reach nearly 25 feet above msl, but drop sharply to less than 7 feet above msl to the west.

Soils—Soils of the Blowing Rocks Preserve are sandy and generally consist of fine quartzipsamments with admixtures of thin organics. They are usually well drained to excessively drained soils that formed in thick deposits of marine sand and fragments of shells, except for those that are associated with tidal swamps. These tidally flushed soils are usually poorly drained and consist of stratified marine sediments often underlain with deep organic peats. Five different soil types have been mapped by the Soil Conservation Service for the Blowing Rocks Preserve and these are closely correlated with present-day vegetation types (U.S.D.A., 1978).

Beaches (Soil Type #25)—Beaches consist of nearly level to sloping, nar-

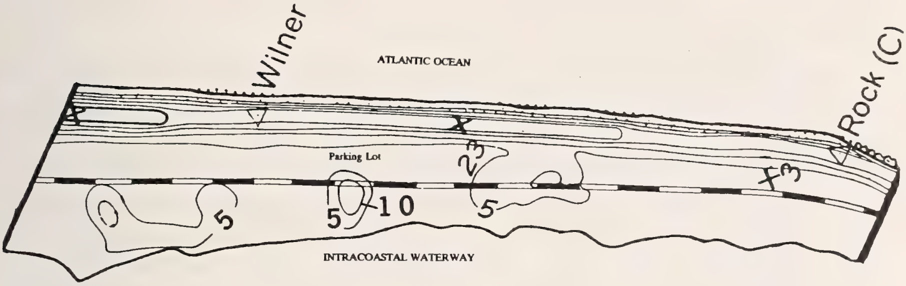

FIG. 1. 1948 Photorevised U.S.G.S. Topographic map of Blowing Rocks Preserve. (Contours in 10 foot intervals)

row strips of wave-washed sands and shell fragments. Rock outcrops are common in the southern portion of the Preserve, however, the rock gives way to a gently sloping beach towards the north. The soil is moderately alkaline and no one pedon dominates the beach area (Fig. 2).

Palm Beach series (Soil Type #8)—Soils of the Palm Beach series are hyperthermic, uncoated Typic Quartzipsamments that are well drained to excessively drained deposits of marine sand and fragments of shell. The soils usually occur on dune ridges and support coastal strand and tropical hammock vegetation within the Preserve. Slopes are usually 0 to 5% but often exceed 8% as they slope westard toward the Intracoastal Waterway.

Canaveral Series (Soil Type #28)—Soils of the Canaveral series are hyperthermic, uncoated Aquic Quartzipsamments that are somewhat poorly drained to moderately drained deposits of sand and shell fragments. These soils occur in the shallow coastal areas on low dunelike ridges and on the side slopes bodering sloughs and mangrove swamps. The Canaveral soils occur in the northwestern part of the Preserve west of State Road 707 and adjacent to the Intracoastal Waterway and in the south from the Intracoastal Waterway to slightly east of State Road 707 (Fig. 2).

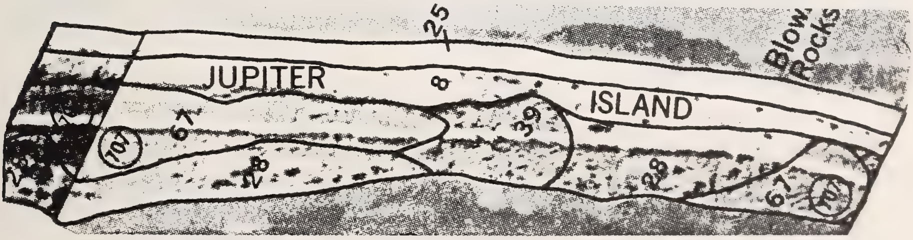

FIG. 2. Soil map of Blowing Rocks Preserve. (Soil Survey of Martin County, U.S.D.A.)

Aquents (Soil Type #67)—These soils are very poorly drained and consist of stratified marine sediments in tidal swamps. The soil material ranges from mixed sand and shell to organic peats at or below sea level with slopes less than 1 percent. Today, these soils support mangrove swamps that occur along both sides of State Road 707 in the northern half and in the extreme southwestern portion of the Preserve and Prairies.

Quartzipsamments (Soil Type #39)—These soils consist of mixed sand and shell materials that have been dredged from adjacent canals at depths ranging from 5 to 20 feet thick. Historical evidence suggests that a major portion of the area west of State Road 707 was used as a fill site during the dredging of the Intracoastal Waterway. A slurry of beach sand and shell was piped from the dredge onto the land and allowed to seek it's own place among the vegetation. Undoubtly, some of the native vegetation was lost or altered with this influx of sand and sea water. The areas immediately at the end of the pipes show up clearly in the 1940 map as white spoil islands (Fig. 3). Along the northern portion of the preserve a steep berm is visible along the eastern edge of the tropical hammock area. This may have been the advancing front of the spoil as it slurried out from the pipes. At least five spoil islands show up in the 1940 map, indicating that a large area was probably covered with several feet of sand.

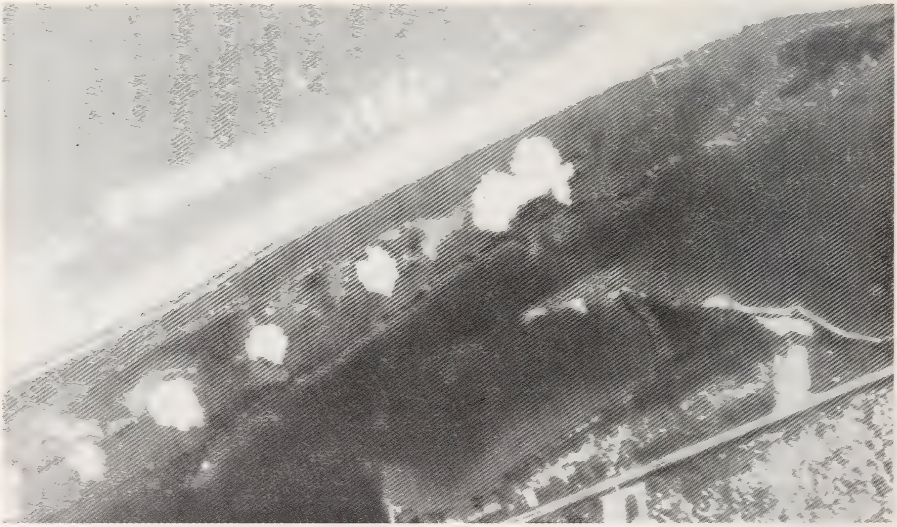

FIG. 3. 1940 U.S.D.A. map showing white spoil areas from dredging Intracoastal Waterway.

Due to the nature of the geology at Blowing Rocks, there is no significant freshwater of usable thickness since most of the recharge occurs from local rainfall which averages about 54 inches per year. Chloride content in the soil increases with proximity to the Intracoastal Waterway and mosquito ditches.

Present-day Plant Communities—Four community types as defined by the Florida Natural Areas Inventory were mapped for the Blowing Rocks Preserve (Fig. 4). The Beach community is considered in this study to be the area from mean high tide up to the edge of the fore dune. Several authors subdivide the beach into the lower, middle and upper beach. However, plant

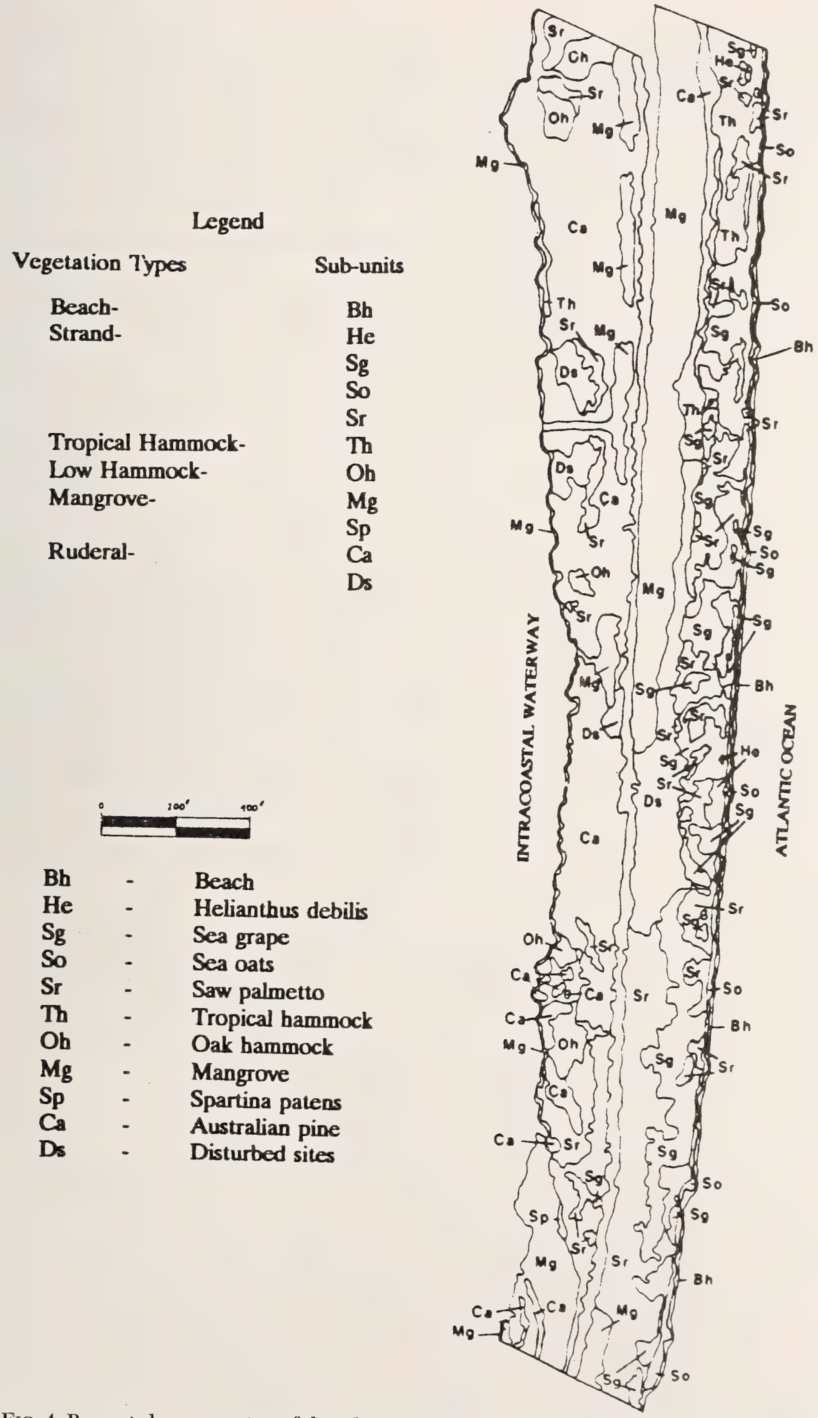

FIG. 4. Present-day vegetation of the Blowing Rocks Preserve.

colonization only occurs in the upper beach zone that is infrequently flooded by tidal activity. This community is often considered the most hostile for plants in Florida because of the high salt content and the sudden changes in sand distribution. Life spans are usually short and succession tends to favor those plants that can tolerate blowing sand. Unlike most Florida beaches, a large portion of the Blowing Rocks Preserve is spared the fury of winter storms because of the protection afforded by the rock outcroppings.

The beach at Blowing Rocks is largely unvegetated, except for species like railroad vine (*Ipomoea pes-caprae*), sea rocket (*Cakile lanceolata*), beach primrose (*Oenothera humifusa*), sea purslane (*Sesuvium portulacastrum*), and bay bean (*Canavalia maritima*) which occur at the base of the coastal fore dune or upper beach. The adversity of the beach community is illustrated by the almost complete lack of faunal associates. The greatest wildlife value is associated with nesting sites for several marine turtles on the sandy beach north of the rock outcroppings. Four species of marine turtles have been observed nesting on the beach within the Preserve: the loggerhead (*Caretta caretta*), the green turtle (*Chelonia mydas*), the leatherback (*Dermochelys coriacea*), and the hawksbill (*Eretmochelys imbricata*). As of the 1988 nesting season for these species, approximately 678 nest were mapped and tagged by Preserve staff. There are approximately 4.51 acres of this community, but this varies with the tides and storms.

From the upper beach to just behind the dune crest lies the Coastal Strand community. Because of the biological diversity of this community within the Preserve, it has been divided into four separate subclassifications: sea oat (So), sea grape (Sg), saw palmetto (Sr), and beach sunflower (He) (Fig. 4). It should be mentioned that the dune vegetation of the fore dune, middle dune and upper dune has been included in this community. Within the south-central portions of the Preserve, Strand vegetation extends from the dune crest westward to State Road 707, whereas, in other locations in the north it is reduced to a thin zone along the narrow face between the beach and the dune crest (old A1A). In total, the acreage of the coastal strand is 32.02 acres or a subtotal of 2.30 acres of sea oats (*Uniola paniculata*), 11.63 acres of sea grape (*Coccoloba uvifera*), 17.82 acres of saw palmetto (*Serenoa repens*), and 0.27 acres of beach sunflower (*Helianthus debilis*). Sea oats, saltmeadow cordgrass (*Spartina patens*), and seashore paspalum (*Paspalum distichum*) form the dominate cover of the dune face at Blowing Rocks. Common associates of the fore dune zone include Spanish bayonet (*Yucca aloifolia*), beach sunflower (*Helianthus debilis*), beach star grass (*Remirea maritima*), necklace pod (*Sophora tomentosa*), half-eaten flower (*Scaevola plumieri*), bay cedar (*Suriana maritima*), and beach lantana (*Lantana involucrata*) (Table 1).

From the dune crest westward toward State Road 707, saw palmetto is the dominant ground cover in admixture with sea grape, blolly (*Guapira discolor*), indigo berry (*Randia aculeata*), marlberry (*Ardisia escallonioides*), coral bean (*Erythrina herbacea*) and several other tropical hardwoods and vines such as wild grape (*Vitis rotundifolia*), Virginia creeper (*Parthenocissus quinquefolia*) and greenbriar (*Smilax auriculata*).

Sheltered from the seabreezes on the back side of the dune lies a thin strip of Maritime Hammock, which has been separated into two important subclassifications within the Preserve; Tropical Hammock (Th) [2.56 acres], that lies primarily east of State Road 707 and Low Hammock (Oh) [2.15 acres] that is mainly located to the west. Tropical hammocks are composed of relatively large, very old hardwood trees of tropical origin which produce a closed canopy forest that becomes wind pruned at the dune crest. The understory is very sparse due to the low light levels imposed by the closed canopy. The term low hammock is used in south Florida (Richardson 1977) to designate any hardwood forest that is mainly dominated by temperate species and generally found on lower elevations than a tropical hammock. Species diversity or richness is higher for tropical hammocks than for other forested systems in Florida. The most common species of the tropical hammock include seagrape (*Coccoloba uvifera*), pigeon plum (*Coccoloba diversifolia*), gumbolimbo (*Bursera simaruba*), mastic (*Mastichodendron foetidissimum*), flexible caper (*Capparis flexuosa*), poison wood (*Metopium toxiferum*), wild coffee (*Phychotria nervosa*), marlberry (*Ardisia escalloniodes*), myrsine (*Rapanea punctata*), rougeberry (*Rivina humilis*), and wild grape (*Vitis rotundifolia*).

In contrast, Low hammocks (2.15 acres) occur along the western edge of the Preserve at slightly lower elevations on soils with somewhat higher moisture levels. Here, sand live oak (*Quercus geminata*) and live oak (*Quercus virginiana*) form the dominant overstory tree species with scattered cabbage palm (*Sabal palmetto*), saw palmetto (*Serenoa repens*), red mulberry (*Morus rubra*), wild poinsettia (*Poinsettia cyathophora*), and several vines such as wild grape (*Vitis rotundifolia*), Virginia creeper (*Parthenocissus quinquefolia*), and greenbriar (*Smilax auriculata*) (Table 1).

Along the middle of the Preserve and adjacent to the Indian River, Estuarine and Marine Tidal Swamps (mangroves) have established themselves in areas where once fresh water marshes were prevalent. These tidal swamps can be divided into two subclassifications: mangroves (Mg), approximately 18.18 acres and *Spartina patens* (Sp), approximately 0.09 acres, for a total of 18.27 acres. Although most of this acreage seems healthy, the mangroves are stressed from the lack of periodic tidal flushing provided by a disconnected system of canals and culverts through openings into the Indian River. Species richness is much lower than would be expected for most mangrove swamps because of the dense shade provided by an overstory of Australian pine (*Casuarina equisetifolia*). Common associates include red mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), black mangrove (*Avicennia germinans*), buttonwood (*Conocarpus erectus*), sea-oxeye daisy (*Borrichia frutescens*), glasswort (*Salicornia virginica*), leatherleaf fern (*Acrostichum danaeifolium*), and coin vine (*Dalbergia ecastophyllum*) (Table 1).

In addition to the 4 natural communities mapped (Fig. 4), Ruderal vegetation makes up about 25% of the total Preserve area. Human impacts, such as

TABLE 1. Checklist of the Vascular Flora of the Blowing Rocks Preserve, Jupiter Island, Florida.

Family	Scientific Name	Common Name	Location[a]
AGAVACEAE			
	Agave decipens	False sisal[b]	6
	Sanseviera hyacinthoides	Bowstring hemp[b]	5,6
	Yucca aloifolia	Spanish bayonet	1,2,3,6
AMARANTHACEAE			
	Alternanthera maritima	Chaff flower	1,2
	Alternanthera ramosissima	Chaff flower	1,2
	Blutaparon vermiculare	Samphire	4
	Iresine diffusa	—	3
AMARYLLIDACEAE			
	Hypoxis juncea	Yellow stargrass	3
ANACARDIACEAE			
	Metopium toxiferum	Poisonwood	2,6
	Schinus terebinthifolius	Brazilian pepper[b]	2,3,4,5
	Toxicodendron radicans	Poison ivy	2,3,5
APIACEAE			
	Centella asiatica	Coinwort	3
	Hydrocotyle umbellata	Marsh pennywort	3
APOCYNACEAE			
	Catharanthus roseus	Periwinkle[b]	2,3,5,6
	Echites umbellata	Devil's potato	2
	Rhabdadenia biflora	Rubber vine	4
ARECACEAE			
	Sabal palmetto	Cabbage palm	2,5,6
	Serenoa repens	Saw palmetto	2,3,5,6
ASTERACEAE			
	Ambrosia artemisiifolia	Ragweed	3
	Aster subulatus	—	3,4
	Baccharis halimifolia	Saltbush	3,4
	Bidens alba	Beggar tick	1,2,3,5
	Borrichia frutescens	Sea-oxeye daisy	2,4
	Conyza canadensis	Horseweed	3
	Eclipta alba	—	3
	Emilia fosbergii	Tasselflower	3
	Emilia sonchifolius	Tasselflower	3
	Erechtites hieracifolia	Fireweed	3
	Erigeron quercifolius	Fleabane	3,4
	Eupatorium capillifolium	Dogfennel	3
	Eupatorium serotinum	—	2,3,4
	Flaveria linearis	Yellow top	3,4
	Gaillardia pulchella	Blanket flower	3
	Gnaphalium falcatum	Cudweed	3
	Gnaphalium pensylvanicum	Cudweed	3
	Helianthus debilis	Beach sunflower	1,2
	Heterotheca subaxillaris	Camphorweed	3
	Iva imbricata	Marsh elder	2,4
	Lactuca graminifolia	—	3,4
	Mikania cordifolia	Hemp vine	2,6
	Mikania scandens	Hemp vine	3,4
	Pluchea camphorata	Marsh fleabane	4
	Pluchea odorata	Saltmarsh fleabane	4
	Pluchea rosea	—	3,4
	Solidago sempervirens	Seaside goldenrod	3,4
	Sonchus oleraceus	Sow thistle	3
	Verbesina virginica	Crownbeard	2,3,6

TABLE 1. CONTINUED

Family Scientific Name	Common Name	Location[a]
Wedelia trilobata	Creeping oxeye[b]	3
AVICENNIACEAE		
Avicennia germinans	Black mangrove	4,5
AIZOACEAE		
Sesuvium portulacastrum	Sea purslane	1,2,4
BATIDACEAE		
Batis maritima	Saltwort	4
BORAGINACEAE		
Heliotropium angiospermum	Beach heliotrop	2,3
BRASSICACEAE		
Cakile lanceolata	Sea rocket	1,2
Lepidium virginicum	Pepper grass	3
BROMELIACEAE		
Tillandsia recurvata	Ball moss	5,6
Tillandsia usneoides	Spanish moss	5
Tillandsia utriculata	Wild pine	5
BURSERACEAE		
Bursera simaruba	Gumbo limbo	5,6
CACTACEAE		
Cereus pentagonus	Dildoe cactus	2,6
Opuntia humifusa	Prickly pear cactus	2,3
CAPPARACEAE		
Capparis cyanophallophora	Jamaica caper	6
Capparis flexuosa	Flexible caper	6
CARICACEAE		
Carica papaya	Papaya[b]	6
CASUARINACEAE		
Casuarina equisetifolia	Australian pine[b]	1,2,3,4,5
CHENOPODIACEAE		
Atriplex pentandra	Beach atriplex	1,2
Chenopodium ambrosioides	Mexican tea	6
Salicornia virginica	Glasswort	4,5
Suaeda linearis	Sea blite	4
CHRYSOBLANACEAE		
Chrysobalanus icaco	Cocoplum	2
Licania michauxii	Gopher apple	2
COMBRETACEAE		
Conocarpus erectus	Buttonwood	4,5
Laguncularia racemosa	White mangrove	4,5
COMMELINACEAE		
Commelina diffusa	Day flower	2
Commelina erecta	Day flower	6
Rhoeo spathacea	Oyster plant[b]	6
CONVOLVULACEAE		
Cuscuta indecora	Dodder	6
Ipomoea alba	Moon flower	5
Ipomoea indica	Beach morning glory	2,6
Ipomoea pes-caprae	Railroad vine	1,2
CRASSULACEAE		
Bryophyllum pinnatum	Live leaf[b]	3,5
CUCURBITACEAE		
Melothria pendula	Creeping cucumber	3,5
Momordica charantia	Wild balsam apple[b]	3,5
CYPERACEAE		
Cyperus globulosus	Sedge	2,3
Cyperus ligularis	—	2,3

TABLE 1. CONTINUED

Family Scientific Name	Common Name	Location[a]
Cyperus odoratus	—	3
Cyperus planifolius	Sedge[b]	3
Cyperus polystachyos	—	3
Cyperus retrorsus	—	3
Cyperus rotundus	—[b]	3
Cyperus virens	Sedge	4
Fimbristylis castanea	—	4
Fimbristylis spathacea	Hurricane grass	3,4
Remirea maritima	Beach star	1,2
DAVALLINACEAE		
Nephrolepis exaltata	Boston fern[b]	5
EUPHORBIACEAE		
Chamaesyce bombensis	Spurge	3
Chamaesyce cumulicola	Sand-dune spurge	3
Chamaesyce hirta	Hairy spurge	3
Chamaesyce hypericifolia	—	2,3
Chamaesyce hyssopifolia	Eyebane	2,3
Chamaesyce maculata	Spurge	2
Chamaesyce mesembyranthemifolia	Beach Spurge	1,2
Chamaesyce opthalmica	—	2,3
Chamaesyce thymifolia	—	2,3
Cnidoscolus stimulosus	Stinging nettle	1,2,3,5
Croton glandulosus	—	3
Croton linearis	Pineland croton	1,2
Croton punctatus	Beach tea	1,2
Drypetes laterifolia	Guiana plum	6
Euphorbia trichotoma	Spurge	1,2
Phyllanthus abnormis	—	2,3
Poinsettia cyathophora	Wild poinsettia	3,5,6
FABACEAE		
Amorpha fruticosa	False indigo	2
Caesalpinia bonduc	Gray nicker	2,5
Canavalia rosea	Bay bean	1,2,5
Chamaecrista fasciculata	Rattle box	3,6
Crotalaria rotundifolia	Rattle box	2
Dalbergia ecastophyllum	Coin vine	2,3,4,5,6
Desmodium incanun	Beggars tick	3,6
Erythrina herbacea	Coral bean	2,3,5,6
Galactia regularis	Milk pea	2,3,5
Indigofera hirsuta	Hairy indigo[b]	3,6
Pithecellobium keyensis	Black pod	2,6
Senna pendula var. glabrata	—	3,5,6
Sophora tomentosa	Necklace pod	2,6
Vicia acutifolia	—	3,5
Vigna luteola	—	3,5
FAGACEAE		
Quercus geminata	Sand live oak	5
Quercus virginiana	Live oak	5
GOODENIACEAE		
Scaevola frutescens	—[b]	1,2,3
Scaevola plumieri	Half-eaten flower	2,6
JUNCACEAE		
Juncus roemerianus	Black rush	4,5
LAURACEAE		
Nectandra coriacea	Lancewood	6
Persea borbonia	Red bay	2,5,6

TABLE 1. CONTINUED

Family Scientific Name	Common Name	Location[a]
LILIACEAE		
Asparagus densiflorus	Asparagus fern[b]	3,5
LOASACEAE		
Mentzelia floridana	Poor man's patch	2,3
LOGANIACEAE		
Polypremum procumbens	Rustweed	3,6
LYTHRACEAE		
Ammannia latifolia	Toothcups	4
MALVACEAE		
Kosteletzkya virginica	Marsh mallow	4
Malvaviscus arboreus	Wax mallow[b]	3
Sida acuta	Broomweed	2,3,4
MORACEAE		
Ficus aurea	Strangler fig	2,4,5,6
Morus rubra	Red mulberry	2,4,5,6
MYRSINACEAE		
Ardisia escalloniodes	Marlberry	2,3,5,6
Rapanea punctata	Myrsine	2,5,6
MYRTACEAE		
Eugenia axillaris	White stopper	6
Eugenia foetida	Spanish stopper	2,5,6
NYCTAGINACEAE		
Boerhavia diffusa	Red spiderling	3,4,6
Guapira discolor	Blolly	2,4,6
OLEACEAE		
Forestiera segregata	Florida privet	2,4,5,6
ONAGRACEAE		
Oenothera humifusa	Beach primrose	2
OSMUNDACEAE		
Vittaria lineata	Shoe-string fern	6
ORCHIDACEAE		
Habenaria odontopetala	Swamp orchid	5
OXALIDACEAE		
Oxalis corniculata	Lady's sorrel	3
PASSIFLORACEAE		
Passiflora suberosa	Passion flower	5,6
PHYTOLACCACEAE		
Phytolacca rigida	Pokeweed	2,3
Rivina humilis	Rougeberry	3,5,6
PLUMBAGINACEAE		
Limonium carolinianum	Sea lavender	4
Plumbago scandens	Leadwort	2,3,5,6
POACEAE		
Andropogon glomeratus var. glaucopsis	Bushy Bluestem	3
Cenchrus incertus	Coast sandspur	1,2,3
Cenchrus tribuloides	Beach sandspur	1,2
Cynodon dactylon	Bermuda grass[b]	3
Distichlis spicata	Saltgrass	1,2
Dactyloctenium aegyptium	Crowfoot grass[b]	3
Digitaria ciliaris	Crab grass	3
Echinochloa walteri	Coast cockspur	2,3
Eleusine indica	Goosegrass[b]	3
Eragrostis elliottii	Love grass	3
Eragrostis nutans	—	3
Eustachys petraea	—	3

TABLE 1. CONTINUED

Family	Scientific Name	Common Name	Location[a]
	Panicum amarum	Beach grass	1,2
	Panicum virgatum	Switchgrass	2,3
	Paspalum distichum	Seashore paspalum	1,2,3,4
	Paspalum floridanum	Florida paspalum	3
	Paspalum setaceum	Thin paspalum	3
	Paspalum urvillei	Vasey grass[b]	3
	Setaria geniculata	Fox-tail grass	3
	Spartina alterniflora	Smooth cordgrass	4
	Spartina patens	Saltmeadow cordgrass	1,2,4
	Sporobolus domingensis	Coral dropseed	3,4
	Sporobolus indicus	Smutgrass	3
	Sporobolus virginicus	Seashore dropseed	1,2,4
	Stenotaphrum secundatum	St. Augustine grass	2,3
	Uniola paniculata	Sea oats	1,2
POLYGALACEAE			
	Polygala grandiflora	Candy root	1,2,3
POLYGONACEAE			
	Coccoloba diversifolia	Pigeon plum	2,5,6
	Coccoloba uvifera	Sea grape	1,2,3,5,6
POLYPODIACEAE			
	Phlebodium aureum	Cabbage palm fern	5,6
	Polypodium polypodioides	Ressurection fern	4,6
PORTULACACEAE			
	Portulaca pilosa	Pink purslane	2
	Portulaca oleracea	Purslane	2,3
PRIMULACEAE			
	Samolus valerandi subsp. parviflorus	Pineland pimpernel	4
PTERIDACEAE			
	Acrostichum danaeifolium	Leatherleaf fern	4,5
RHAMNACEAE			
	Colubrina asiatica	Lather leaf[b]	3,5
	Krugiodendron ferreum	Ironwood	6
RHIZOPHORACEAE			
	Rhizophora mangle	Red mangrove	4,5
RUBIACEAE			
	Chiococca alba	Snowberry	2,3,5,6
	Ernodea littoralis	Beach creeper	2
	Hedyotis corymbosa	—	3
	Morinda royoc	Cheese weed	1,2
	Psychotria nervosa	Wild coffee	3,5,6
	Psychotria sulzneri	Wild coffee	3,5,6
	Randia aculeata	Indigo berry	2,3,6
	Richardia brasiliensis	—[b]	3
	Spermacoce assurgens	—	3
	Spermacoce verticillata	—	3
RUTACEAE			
	Amyris elemifera	Torchwood	6
	Zanthoxylum fagara	Wild lime	5,6
SALICACEAE			
	Salix caroliniana	Carolina willow	4
SAPINDACEAE			
	Exothea paniculata	Inkwood	6
SAPOTACEAE			
	Bumelia celastrina	Saffron plum	2
	Bumelia salicifolia	Bustic	2,6

TABLE 1. CONTINUED

Family Scientific Name	Common Name	Location[a]
Chrysophyllum oliviforme	Satin leaf	6
Mastichodendron foetidissimum	Mastic	6
SCROPHULARIACEAE		
Bacopa monnieri	Water hyssop	4
Linaria canadensis	Toadflax	3
SIMAROUBACEAE		
Simarouba glauca	Paradise tree	5,6
SMILACACEAE		
Smilax auriculata	Greenbriar	2,3,5,6
SOLANACEAE		
Physalis viscosa var. maritima	Ground cherry	2,3,5
Solanum americanum	Night shade	3
Solanum erianthum	Potato tree	3,6
SURIANACEAE		
Suriana maritima	Bay cedar	1,2
TYPHACEAE		
Typha domingensis	Southern cattail	4
URTICACEAE		
Parietaria floridana	Pellitory	2
VERBENACEAE		
Citharexylum fruticosum	Fiddlewood	3
Lantana camara	Lantana	3
Lantana involucrata	Beach lantana	2,3
Lippia nodiflora	Creeping charlie	3
Verbena maritima	Beach verbena	2,3
VITACEAE		
Parthenocissus quinquefolia	Virginia creeper	3,5,6
Vitis rotundifolia	Wild grape	2,3,5,6
Vitis shuttleworthii	Calusa grape	6
ZYGOPHYLLACEAE		
Tribulus cistoides	Puncture vine[b]	2,3

[a] Location Key: (1) Beach/Dune, (2) Strand, (3) Ruderal, (4) Mangrove, (5) River area/Low hammock, (6) Tropical Hammock.
[b] Denotes non-native species.

dredging of the Intracoastal Waterway and excavation of mosquito ditches, have created many disturbed areas within the natural setting. Generally, there are about 28.56 acres of ruderal or disturbed site vegetation within the Preserve. This vegetation type can be further divided into 22.75 acres of Australian pines (Ca) and 5.81 acres of cleared or disturbed (Ds) land. Common species associated with this community include Australian pine (*Casuarina equisetifolia*), Brazilian pepper (*Schinus terebinthifolius*), ragweed (*Ambrosia artemisiifolia*), beggar tick (*Bidens alba*), pokeweed (*Phytolacca americana*), periwinkle (*Catharanthus roseus*), pepper grass (*Lepidium virginicum*), wild balsam apple (*Momordica charantia*), nutsedge (*Cyperus ligularis*), and lather leaf (*Colubrina asiatica*).

Vegetation Transects—A sampling program was established to depict the collective change in species composition along a topographic gradient from the open beach westward to the Intracoastal Waterway within the Blowing Rocks Preserve. Three line-transects located within the preserve proper (Fig. 5) were

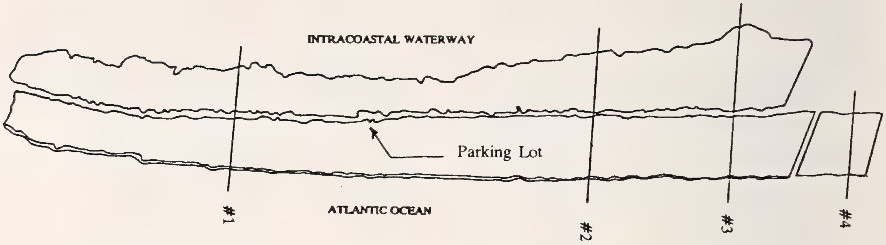

FIG. 5. Location of line-transects used for vegetation analysis of the Blowing Rocks Preserve. (Transect #4 is about 600 ft. north of preserve)

randomly located in an east-west direction on the ground from the edge of the rock outcrop near the beach to the Intracoastal Waterway and all crowns that overlapped or intercepted the line were recorded by species to the nearest centimeter. A fourth line-transect was established in a portion of the tropical hammock located on Nature Conservancy property north of the preserve proper. Since the disjunct transect had no immediate bearing on the management plan of the main preserve, no cover estimates were included. The accumulated length occupied by any one species out of the total meter tape length used for each transect was expressed as the percent cover for that species.

The results indicated that species richness was much higher for Transect #3 (Fig. 6) than for the two transects to the south (Figs. 7 and 8). A total of 38 species was associated with Transect #3, compared to 21 species for Transects 1 and 2, respectively. The higher richness to the north was due to the occurrence of tropical hammock vegetation, which normally supports many more species than either beach or strand vegetation (Alexander and Crook, 1973).

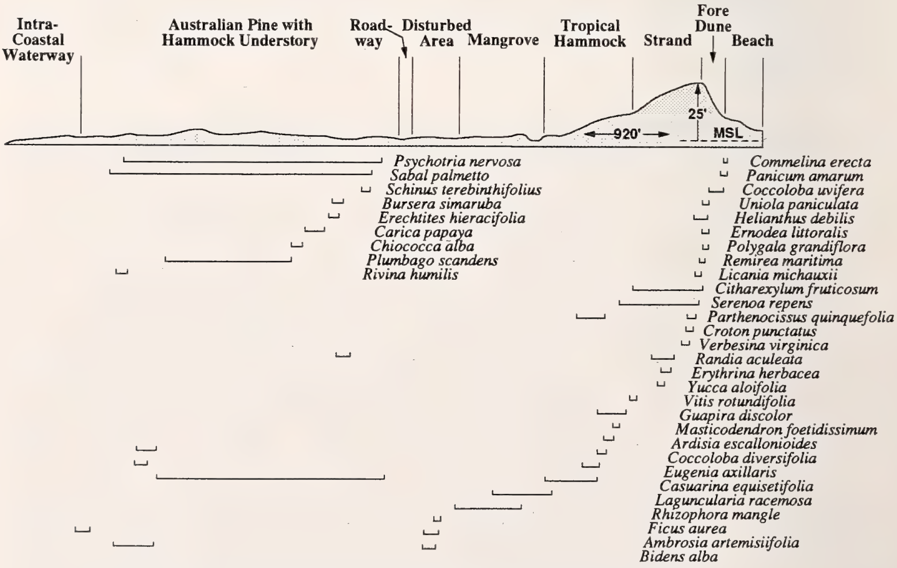

FIG. 6. Dune profile of the Blowing Rocks Preserve along Transect #3.

Total plant coverage was complete (100.23 and 99.98% of the total transect) for both Transects #1 and 3, respectively. Transect #2 showed reduced coverage (79.39%) estimates due to open water associated with the mangrove/mosquito ditches and small areas of spoil.

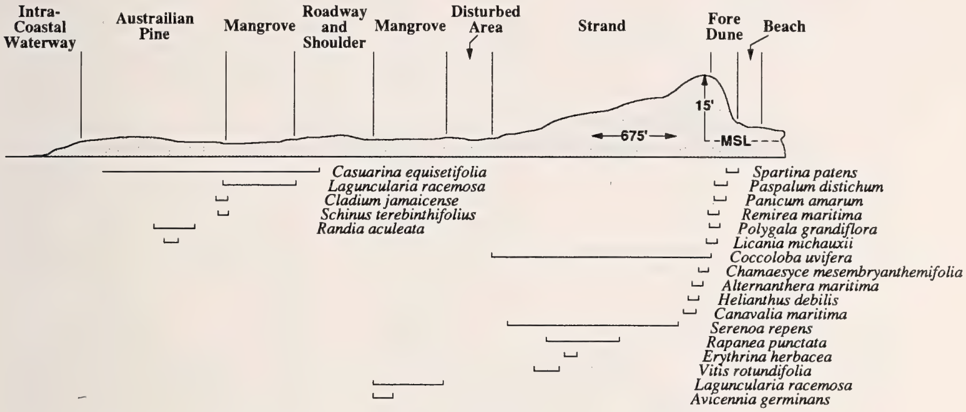

FIG. 7. Dune profile of the Blowing Rocks Preserve along Transect #2.

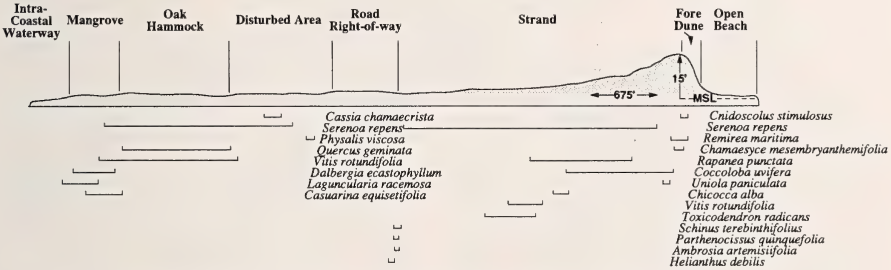

FIG. 8. Dune profile of the Blowing Rocks Preserve along Transect #1.

Historic Vegetation Patterns—Historical evidence indicates that a vast majority of the Blowing Rocks Preserve was tropical hammock along the Intracoastal Waterway and strand vegetation toward the east to the dune crest prior to 1900 (Fig. 9). Mangroves were common in the Jupiter narrows and along the western edge of the secondary dune within the Preserve as early as the mid 1800's. The Taney map (Fig. 10), at first glance, indicated that a vast majority of the preserve was freshwater marsh. However, when the entire map was obtained, it was clear that the symbols used for mangroves and freshwater marsh did not correspond to the symbols used on Jupiter Island.

Griswold (1896) and Shaler (1890) further described south Florida as a vast waterway with water levels up to 8-10 feet above mean sea level. This large fresh water head from the Loxahatchee River, coupled with tidal fluctuations, probably infrequently flooded this area which is less than 3 feet above mean sea level. The influence of salt water into Jupiter Sound was minimal as

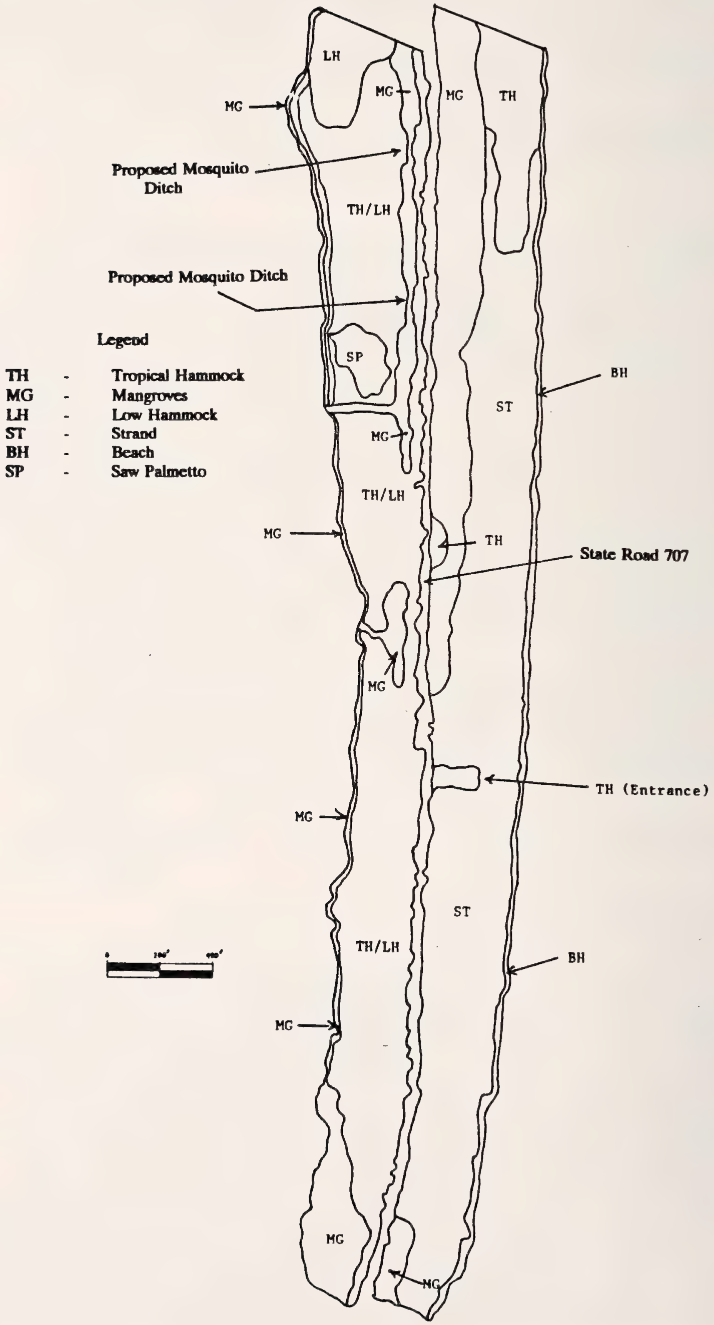

FIG. 9. Historic vegetation patterns of the Blowing Rocks Preserve prior to 1940.

the presence of mangroves was restricted to areas near Jupiter Inlet in the late 1800's. However, the principal effect of the early settlers was to open the inlet for navigation and drain the land by increasing discharge from the Everglades through a series of canals. Much of this early drainage was uncontrolled and estimates indicate that water levels were lowered generally 5-6 feet (Leach et al., 1972). The final result of both of these practices was the eventual transgression of a fresh water system to a salt water estuary.

The occurrence of mangroves within Blowing Rocks was not documented until the early 1940's, following the deposition of spoil from dredging the Intracoastal Waterway. The Taney map (1883) does indicate that some mangroves occurred just north of the preserve on some of the finger-like projections that jut out into Hobe Sound. Today, the area west of State Road 707 is primarily dominated by Australian pine (*Casuarina equisetifolia*), with scattered pockets of low hammock, tropical hammock, and mangroves.

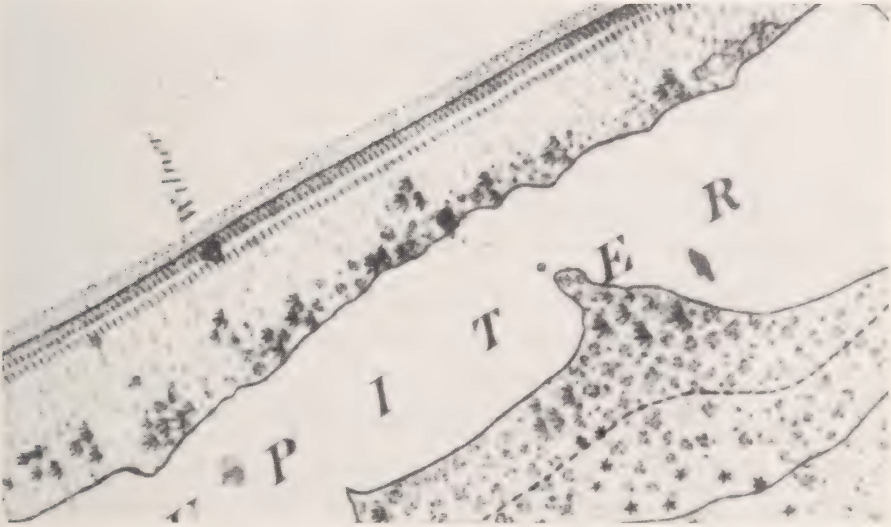

FIG. 10. Taney Map (1883) of the Blowing Rocks Preserve.

Plant Species—A checklist of the vascular flora of the Blowing Rock Preserve was produced over a three year period between 1984-1987. A total of 233 plant species representing 75 families were recorded for the preserve area. Species richness is much higher for this site than for other beach/dune systems to the south such as Boynton Beach Hammock (n= 98 species) and Boca Hammock (n=137 species). This large number of plant species may be partly attributed to lack of human pressure from surrounding development. On the basis of species composition, 23 exotic species or about 10% of the flora associated with Blowing Rocks is non-native to Florida. This low percentage of non-native species indicates a relatively intact native flora despite mosquito ditching, soil deposition, pedestrian traffic, and past road building within the preserve. Two exotic plant species pose a serious management problem to the integrity of the Blowing Rocks Preserve. Australian pine (*Casuarina equisetifolia*) may have been introduced into the scrub dunes of Hobe Sound as early as the early 1920's (Small, 1924), while lather leaf (*Colubrina asiatica*) was first observed along the Intracoastal Waterway in the preserve about 1978 (Austin, 1978). A management program has been implemented to curtail or remove these noxious pest species.

The nomenclature follows Wunderlin (1982), and some voucher material has been collected and deposited at Fairchild Tropical Gardens.

Designated Animal and Plant Species—In general, the natural resources of barrier islands exhibit a number of unusual characteristics which support the contention that these islands represent a totally unique ecosystem. Many oceanic species, such as sea turtles, maintain their ties to these areas. Some terrestrial species, such as ghost crabs (*Ocypode*), must have this link with the marine environment and, for still others, such as several species of wading birds, these sites are much needed supportive areas.

Probably one of the most important influences on the uniqueness of this island's wildlife resources is its insularity, that is, the isolation of the island and the biological implications of that isolation. When a species does succeed in reaching an island, some of the mainland constraints are left behind. These areas also favor genetic drift and the evolution of new forms that are distinct from their mainland ancestors.

The number of aquatic and terrestrial organisms considered associated with this island is great and uses vary from the smallest plankton and insects to the largest birds and mammals. At least 13 plant species of endangered, threatened, rare, commercially exploited, or species of special concern status occur within the Preserve and are referenced by one or more federal or state regulatory agencies, as well as other listings. A listing of the designated plant species which occur in the Preserve is provided: *Acrostichum danaeifolium* (Threatened, FDA), *Cereus pentagonus* (Threatened, FDA; Appendix II Species, CITIES), *Chamaesyce cumulicola* (C2, USFWS), *Chrysophyllum olivaeforme* (Endangered, FDA), *Ernodea littoralis* (Threatened, FDA), *Habenaria odontopetala* (Threatened, FDA; Appendix II Species, CITES), *Phlebodium aureum* (Threatened, FDA), *Remirea maritima* (Endangered, FDA), *Scaevola plumieri* (Threatened, FDA), *Verbena maritima* (Endangered, FDA; C1, USFWS), *Tillandsia utriculata* (Commercially Exploited, FDA), *Suriana maritima* (Endangered, FDA), and *Vittaria lineata* (Threatened, FDA) (Wood, 1991). [FDA–Florida Department of Agriculture and Consumer Services; USFWS–United States Fish and Wildlife Service; CITES–Convention on International Trade in Endangered Species of Wild Fauna and Floras.]

Except for migratory avifauna and sea turtles, resident protected animal species have not been observed or studied for this site. Excellent data regarding the use of the north end of the preserve as nesting sites for protected sea turtles has been an ongoing study of the preserve staff. Four species of marine turtles have been observed nesting on the north beach. These include: *Caretta caretta* (Threatened, FGFWFC, USFWS, CITES I), *Chelonia mydas* (Endangered, FGFWFC, USFWS, CITES I), *Dermochelys coriacea* (Endangered, FGFWFC, USFWS, CITES I), *Eretmochelys imbricata* (Endangered, FGFWFC, USFWS, CITES I). [FGFWFC–Florida Game and Fresh Water Fish Commission; USFWS–United States Fish and Wildlife Service; CITES I–Convention on International Trade in Endangered Species of Wild Fauna and Floras.]

These preliminary findings indicate that, despite a recent past history of anthropogenic changes, the beach/dune vegetation is still intact and well-developed for this barrier island preserve. Exotic invasion is relatively low (ca. 10%) and a replanting program has been initiated by The Nature Conservancy in an attempt to replace former beach/dune systems that have been partially lost over the past 75 years.

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LITERATURE CITED

Alexander, T. R. and A. G. Crook. 1973. Recent and long-term vegetation changes and patterns in South Florida—Part I, Prel. Rept. National Technical Information Service, U.S. Dept. of Commerce, Washington. D.C. Accession No. PB-231-939 (1974).

Andrews, E. W. and C. M. Andrews. 1981. Jonathon Dickinson's Journal. Florida Classics Library. Stuart, Florida. 109 pp.

Austin, D. F. 1978. Exotic Plants and their effects in Southeastern Florida. Environmental Conservation 5(1): 25-34.

DuBois, B. W. 1957. Celt and pendant from Jupiter Inlet, Florida, mound. Florida Anthropologist 27:67-76.

First National Bank & Trust Company of Stuart. 1973. Martin County. Southeastern Marketing/Communications, Stuart, Florida. 36 pp.

Griswold, L. S. 1896. Notes on the geology of Southern Florida. Harvard Coll. Mus. Comp. Zoology Bull. 28(2).

Henshall, J. A. 1884. Camping and cruising in Florida. Robert Clarke and Co. Cincinnati.

Leach, S. D., H. Klein, and E. R. Hampton. 1972. Hydrologic effects of water control and management of southeastern Florida. U.S. Geol. Surv., Rept. of Investigations, No. 60:43-47. Tallahassee.

Lund, F. 1988. Jupiter, FL. Pers. Comm.

________, F. 1979. The Nature Conservancy Preserve Master Plan for Blowing Rocks Preserve. Unpublished.

Richardson, D. R. 1977. Vegetation of the Atlantic Coastal Ridge of Palm Beach County, Florida. Florida Scient. 40(4): 281-330.

Scherer, L. 1988. Hobe Sound, Fl. Pers. Comm.

Shaler, N. S. 1890. The topography of Florida. Harvard Coll. Mus. Comp. Zoology Bull. 16(7): 139-158.

Small, J. K. 1924. The land where spring meets autumn. J. New York Bot. Gard. 25:53-94.

Tebeau, C. W. 1971. A History of Florida. Univer. Miami Press, Coral Gables, Fl.

The Martin County Historical Society. 1975. History of Martin County. Gilbert's Bar Press, Hutchinson Island, Martin County, FL. 419 pp.

U.S.D.A. 1978. Soil survey of Palm Beach County, Florida. Soil Conservation Service. 96 pp.

VandeWeghe, R. 1989. Hobe Sound, FL. Pers. Comm.

Williams, J. L. 1837. The territory of Florida: or sketches of the topography, civil and natural history, of the county, the climate and Indian tribes, from the first discovery to the present time, with map, views and comments. A. T. Goodrich Press, New York, NY.

Wood, D. 1991. Official Lists of Endangered and Potentially Endangered Fauna and Flora in Florida, 1 April 1991. Fla. Game & Fresh Water Fish Comm., Tallahassee, FL. 23 pp.

Wunderlin, R. P. 1982. Guide to the Vascular Plants of Central Florida. Univ. South Florida Press, Tampa.

Ziemba, C. 1968. Historiography: Jupiter Island road was Palm Beach County move. The Stuart News, Stewart, FL.

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BURIED DORMANT SEEDS IN BOTTOM SEDIMENTS OF NEWNANS LAKE, FLORIDA.

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ABSTRACT: *Buried seed densities in bottom sediments near the shores of Newnans Lake, Florida were estimated in 21.24 cm*^{2}*, 10 cm deep cores collected at each of five water depths: 30, 40, 55, 80 and 120 cm. Germination in a greenhouse was used to determine viable seed density in the 32 samples. Ten herbaceous species and zero woody species germinated over a 12 week period. The number of germinated seeds ranged from 0 to 51 seeds per 21 cm*^{2} *sample and averaged 2,766 seeds/m*^{2}*; there was no apparent trend with depth. Relatively low densities of buried seeds in bottom sediments in Newnans Lake compared with other lakes may be the result of 24 years of dampened lake level fluctuations due to a dam across Prairie Creek, the lake's major outflow.*

ALTHOUGH propagules produced by plants along lake shorelines undoubtedly colonize bottom sediments when water levels recede, viable seeds buried in bottom sediments may contribute substantially to the newly established littoral vegetation. Along lakeshores in Ontario, for example, the species composition of the bottom sediment seed bank is a good predictor of post-drawdown vegetation (Keddy and Reznicek, 1982); mean densities of buried seeds in these sediments range from 10,089/m^2 (Keddy and Reznicek, 1982) to 36,639/m^2 (Nicholson and Keddy, 1983). Where water levels in lakes are artificially maintained at high levels, herbaceous littoral vegetation suffers and rates of seed input into the bank of dormant buried propagules in bottom sediments is probably reduced. Water level control structures may therefore influence reestablishment of littoral vegetation even after they are removed and water level fluctuations are unencumbered.

Newnans Lake, a 3000 ha eutrophic water body (Canfield, 1981) approximately 8 km east of Gainesville, Florida (maximum depth = 3.6 m, mean depth = 1.5 m; Nordlie, 1976) was dammed at its primary outflow from 1967 to March 1991 to facilitate boat access during drought years. The climate of the area is warm temperate with a mean annual temperature of 21°C, and a mean annual rainfall of approximately 1370 mm (Dohrenwend, 1978). Apparently in response to dampened water level fluctuations the herbaceous littoral fringe has become extremely sparse, the lake edge is now dominated by *Taxodium distichum* (bald cypress), and gamefish populations have declined (Gottgens and Montague, 1987). To determine the possible contribution of buried dormant seeds to the littoral vegetation anticipated to develop in response to removal of the water level control structure on Newnans Lake, we conducted a seed bank survey at different depths and distances from the current shoreline before the dam was removed.

METHODS—Seed bank samples on the top 10 cm of bottom sediments were collected during the first week of February 1991 using a 5.2 cm diameter pipe. Thirty-two cores were collected at random locations along the south shore of Newnans Lake at depths of 30, 40, 55, 80 and 120 cm. A rangefinder was used to measure the distance from treeline of each sample. The water level at the date of collection was 19.9 m MSL (U.S. Geological Survey, 1991). Each of the 32 cores was spread over a mixture of perlite and vermiculite in 25 x 15 cm flats in a greenhouse. Two additional samples to be used as controls for potential seedfall in the greenhouse were baked at 225°C for 60 minutes to destroy any seeds in the soil. The trays were exposed to natural sunlight and were kept moist. Mean daily maximum temperature was 29°C, and mean daily minimum temperature was 16°C. After 12 weeks, all seedlings were counted and identified.

RESULTS AND DISCUSSION—The number of germinated seeds was extremely variable among samples but averaged 2,771 seeds/m^2 (Table 1). This value is low compared with the 10,089-36,639 seeds/m^2 reported for lake bottom sediments in Canada (e.g., Keddy and Reznicek 1982; Nicholson and Keddy, 1983), but is high compared with the failure to find any seeds in samples collected from the center of Newnans Lake (Skoglund, 1990). A total of 7 species of monocots and 3 species of dicots germinated from the samples (Table 2). *Sacciolepis striata* (American cupscale grass) was the first species to germinate and the most abundant plant in the flats; no woody plants germinated from the samples and no seedlings appeared in the control flats. Neither distance from shore (0-35 m) nor water depth was significantly correlated with number of seeds germinating ($r_s = 0.25$ and $r_s = -0.03$, respectively). For unknown reasons, seedlings tended to be more abundant in sediment samples collected on the western side of the lake.

TABLE 1. Germinated seeds per 21.24 cm^2 sample of the top 10 cm of bottom sediments from Newnans Lake (N = 32).

	Number of seedlings by depth (cm)				
	30	40	55	80	120
	1	22	0	17	4
	11	3	32	4	2
	1	9	0	1	
	3	3	0	0	
	0	3	0	0	
	4	0	1	4	
		0	2		
		4	51		
			6		
			0		
Mean seeds/m^2	1570	2590	4332	2040	1413

If water level fluctuations are important for the maintenance of wetland seed banks (Leck et al. 1989), then in addition to contributing to the demise of the littoral fringe of herbaceous vegetation, the damming of Newnans Lake may have decreased the density of seeds in its bottom sediments. It remains to be seen, however, whether the species composition and relative paucity of buried seeds will influence the rate of plant establishment now that the dam is open and bottom sediments will be exposed.

TABLE 2. The total number of germinated seeds in 21.24 cm^2 samples of 10 cm deep lake bottom sediments (N = 32).

	Water Depth (cm)				
Species	30	40	55	80	120
Pentodon pentandrous	10	9	14		
Eupatorium capillifolium		3	1		
Oxalis sp.	4	3	4	4	2
Echinochloa walteri		1	4	2	
Leersia quadraga	2			1	
Sacciolepis striata	3	16	40	8	
Cyperus strigosus	1	5	16	6	2
Typha domingensis ?		3	4	1	
Unknown grass		2	8	2	2
Unknown monocot		2	1	2	
Total germinated seeds	20	44	92	26	6
Number of samples	6	8	10	6	2
Mean seeds/m^2	1570	2590	4332	2040	1413

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LITERATURE CITED

CANFIELD, D. E., JR. 1981. Chemical and trophic state characteristics of lakes in relation to regional geology. Final report, Cooperative Fish and Wildlife Unit, University of Florida, Gainesville, FL.

DOHREWEND, R. E. 1978. The climate of Alachua County, Florida. IFAS Bulletin 796, Univ. Florida, Gainesville, FL.

GOTTGENS, J. F. AND C. L. MONTAGUE. 1987. Orange, Lochloosa, and Newnans Lakes: A survey and preliminary interpretation of environmental research data. Department of Environmental Engineering Sciences, University of Florida, Gainesville, FL.

KEDDY, P. A. AND A. A REZNICEK. 1982. The role of seed banks in the persistence of Ontario's coastal plain flora. Amer. J. Bot. 69: 13-22.

LECK, M. A., V. T. PARKER, R. L. SIMPSON (eds.). 1989. Ecology of Soil Seed Banks. Academic Press Inc., Orlando, FL.

NICHOLSON, A. AND P. A. KEDDY. 1983. A depth profile of a shoreline seed bank in Matchedash Lake, Ontario. Can. J. Bot. 61: 3293-3296.

NORDLIE, F. G. 1976. Plankton communities of three Central Florida lakes. Hydrobiologia 48: 65-78.

SKOGLUND, R. R. 1990. Newnans Lake profile. Report to the Florida Game and Fresh Water Fish Commission, Kissimmee.

U.S. GEOLOGICAL SURVEY. 1991. unpublished records. U.S. Department of the Interior, Jacksonville, FL.

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IMPINGEMENT OF ORGANIC-RICH, CONTAMINATED SEDIMENTS ON MANATEE POCKET, FLORIDA

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Abstract: *Fine-grained, organic-rich sediments are adversely impacting portions of the coastal zone in Florida. One extreme example is found in Manatee Pocket, on the southeastern coast of Florida, where sediments with >4% organic carbon have an average thickness of about 1 m and a total volume of 340,000 m*^{3}*. These deposits formed as soil and organic matter were carried into Manatee Pocket and trapped during the past 100 years of regional development. Vertical profiles for Cd, Cu, Hg, Pb, and Zn show that contamination, at 5-10 times above natural levels, is restricted to the top 15-30% of the organic-rich layers of sediment. Thus, despite a long history of sedimentation problems, incoming sediments have been burdened with contaminants only since the 1950s.*

Coastal waterways in Florida and worldwide are being stressed by inputs of fine-grained, organic-rich sediment (Fernald and Patton, 1984; Trefry et al., 1990). One common stress is depletion of oxygen in sediments and bottom water as the result of decaying organic matter. Benthic habitats are altered when the natural sandy substrate is covered with a black, fine-grained, sediment ooze. In addition, resuspension of such sediments increases turbidity and inhibits light penetration leading to a decline in the growth of seagrasses. Finally, contaminants are effectively adsorbed and stored by this high surface area material.

One noteworthy site of impact in Florida is Manatee Pocket, where large amounts of fine-grained, organic-rich sediment have been trapped. Manatee Pocket is part of the St. Lucie Estuary and is located near the confluence of the estuary with the Indian River Lagoon and the Atlantic Ocean (Fig. 1). Water depths in the pocket are typically 1-2 m and salinities range from <1‰ in adjacent creeks to >30‰ throughout much of the embayment. Available data for surficial sediments show elevated levels of Cd, Cu, Hg, Pb, Zn, chlordane, and PCBs (Davis, 1987; Haunert, 1988). More detailed knowledge of the vertical and horizontal distribution and magnitude of contamination is required to plan pollution prevention and remediation strategies.

Methods—Field sampling in Manatee Pocket was carried out during April 6 and 7, 1989 using a small, shallow-draft vessel. Twelve sediment cores were collected, eight with a Benthos gravity corer and four with a vibra corer. Each core penetrated through fine-grained, organic-rich sediment to sand or shell. Core lengths ranged from 19-204 cm, averaging 122 cm. Each core was split longitudinally to describe sediment lithology and then subsectioned into 1-cm intervals over the top 10 cm and 2- to 5-cm thick layers below 10 cm. Surficial sediments (top 2 cm) were collected by a diver at 21 locations (Fig. 1). All sediment samples were placed into tared plastic vials, weighed, freeze-dried, and then reweighed to determine water content. A small portion of each sample was saved wet for Hg analysis.

Total concentrations of Al, Cd, Cu, Fe, Pb, and Zn in sediments were determined by atomic

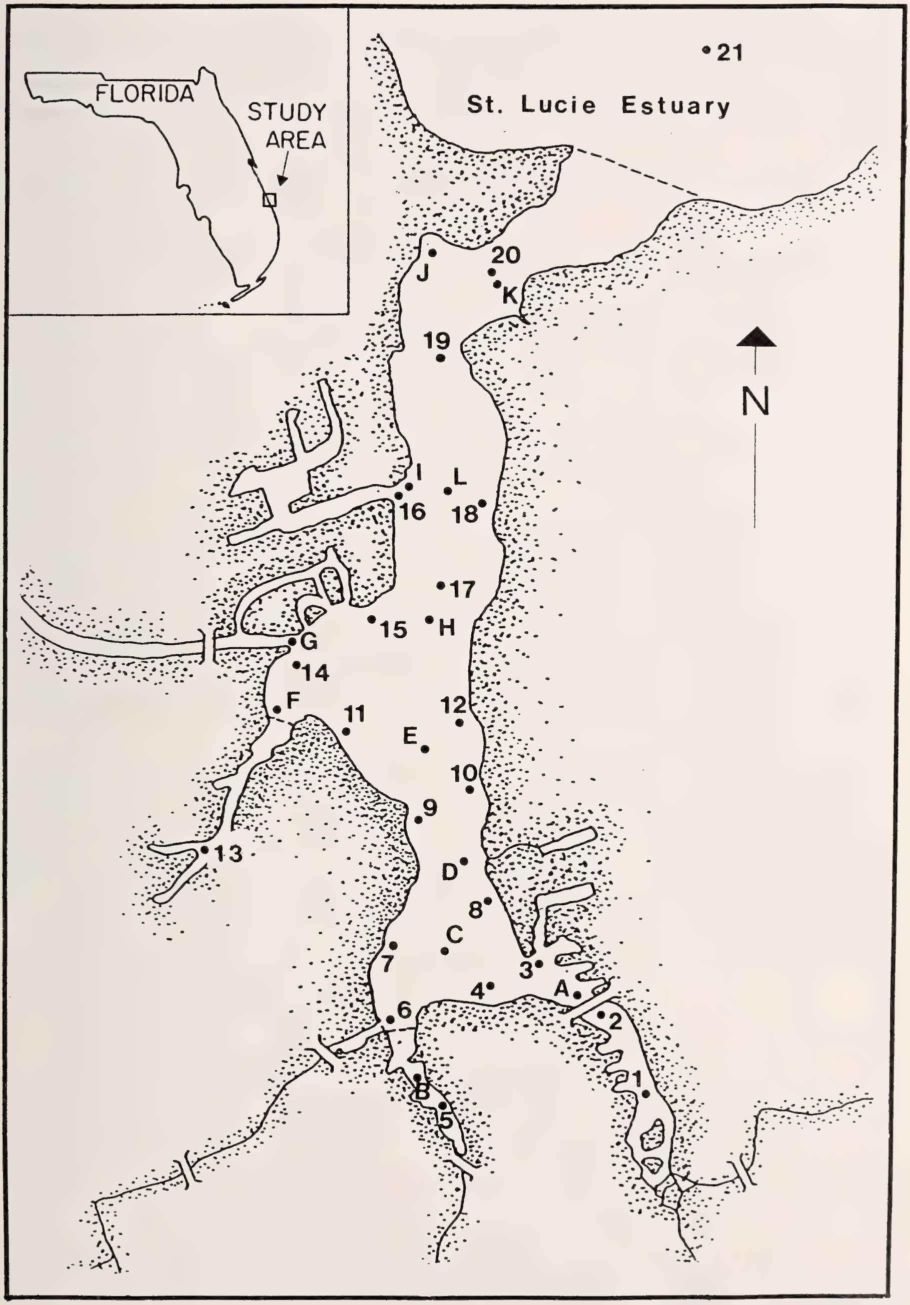


FIG. 1. Map showing sampling stations for Manatee Pocket with inset map identifying site location on the southeastern coast of Florida. Numbers identify locations of surface grab samples and letters show core sites.

absorption spectrophotometry (AAS) following complete digestion of 0.4 g samples using HNO_3-HF-$HClO_4$ in Teflon beakers fitted with Teflon watch covers as described in Trefry and Metz (1984). Sediment solutions and reagent blanks were analyzed using a Perkin-Elmer model 4000 instrument equipped with deuterium and tungsten background correction as well as an HGA-400 heated graphite atomizer and an AS-40 autosampler. Concentrations of Al, Cu, Fe, and Zn were determined by flame AAS and values for Cd and Pb were obtained using heated graphite atomization.

Sediment Hg values were determined by heating separate 2-g aliquots of sediment with 5 mL of concentrated, redistilled HNO_3 in a 65°C water bath for 1 hour. The reaction was carried out in acid-washed, polypropylene centrifuge tubes. After heating, the samples were cooled to room temperature, centrifuged, transferred to a graduated cylinder, and diluted to a final volume of 25 mL with distilled, deionized water. Analyses were carried out by cold-vapor AAS using a Laboratory Data Control Mercury Monitor.

Concentrations of total organic carbon, total nitrogen, and total sulfur were determined using a Carlo-Erba NA1500 nitrogen/carbon/sulfur analyzer. Samples were acidified with HCl to drive off inorganic carbon and dried in an oven at 70°C. The concentrations of C, N, and S were determined following combustion of 10-mg samples in tin cups at 1000°C. The carbonate content of the sediments was measured using the gasometric technique of Schink and co-workers (1978). Silicon concentrations were determined on separate aliquots of sediment following digestion in sealed Teflon tubes to prevent volatilization and loss of Si as SiF_4. Analysis followed by flame AAS.

Analytical precision was determined using replicate samples and was better than 10% for each element. Accuracy was determined by analysis of certified standard reference materials (SRM) available from the National Institute of Standards and Technology (NIST) and the National Research Council of Canada (Table 1).

Sediment accumulation rates and age determinations were measured by Pb-210 and Cs-137 geochronologies. The gamma activities of Pb-210 at 46.5 keV, Pb-214 at 351.8 keV, and Cs-137 at 661.6 keV were determined using a Princeton Gamma-Tech intrinsic germanium detector (Cutshall et al., 1983). Counting efficiencies and accuracy were determined by analyzing SRM 4350B, an NIST sediment sample calibrated for environmental radioactivity, and samples from Manatee Pocket that were spiked with Pb-210 and Cs-137.

TABLE 1. Concentrations for trace metals in Standard Reference Material #1646, an estuarine sediment prepared by the U.S. National Institute for Standards and Technology and for carbon, nitrogen, and sulfur in MESS-1, a marine sediment prepared by the National Research Council of Canada.

Element	Certified Concentration	This Study (n=10)
Al	6.25 ± 0.20%	6.18 ± 0.07%
Cd	0.35 ± 0.07 ppm	0.40 ± 0.03 ppm
Cu	18 ± 3 ppm	18.2 ± 0.7 ppm
Fe	3.35 ± 0.10%	3.36 ± 0.06%
Pb	28.2 ± 1.8 ppm	26.2 ± 1.6 ppm
Si	31%*	30.9 ± 0.6%
Hg	63 ± 12 ppb	65 ± 3 ppb
Zn	138 ± 6 ppm	126 ± 4 ppm
C	2.99 ± 0.09%	2.98 ± 0.07%
N	—	0.195 ± 0.003%
S	0.72 ± 0.05%	0.72 ± 0.04%

*Reference concentration.

RESULTS AND DISCUSSION—*Sediment distribution and composition*—The shape and bathymetry of Manatee Pocket (Fig. 1) combine to trap much of the fine-grained material carried in from adjacent creeks and canals. Thus, fine-grained, organic-rich, sediments were found at virtually every site. In this paper, we use the term "muck" loosely to describe black, fine-grained (>60% silt and clay-size particles), organic-rich (>4% organic carbon) sediments with a high water content (>75% water by weight) (Trefry et al., 1990). McNulty and McNulty (1987) found that the thickness of muck sediments in the pocket varied from 0-259 cm with an average of 135 cm. We found muck sediments extending to depths >200 cm with an average thickness of 84 cm. The larger deposits were generally found in the center of the pocket at deeper water depths where settling and deposition are favored. No muck deposits were found in the adjacent, well-flushed portion of the lower St. Lucie Estuary (Fig. 1).

The total amount of fine-grained, organic-rich sediment in Manatee Pocket was calculated by dividing the area into 63 blocks and using data from our work and that of McNulty and McNulty (1987) for the thickness of organic-rich sediment. These thicknesses were multiplied by the appropriate area to calculate a volume for each block. The total volume of wet, muck sediment for Manatee Pocket is 340,000 m^3. When admixed sand and shell layers are included, this sediment averages about 60% water by weight or 80% water by volume. Thus, the volume of dry sediment is 68,000 m^3 with a mass of 177,000 metric tons (dry density=2.6 g/cm^3). The wet volume of organic-rich sediment for Manatee Pocket is similar to the 270,000 m^3 of wet muck estimated for the Hillsborough River and adjacent river mouth basin in Tampa, Florida (Trefry et al., 1989). This pool of organic matter in Manatee Pocket provides abundant energy for sediment bacterial assemblages to create the observed high sediment oxygen demand that leads to anoxic conditions (Davis, 1987).

Sediments rich in organic carbon persist throughout each core as shown for Station H (Fig. 2). An average of 5.5±3.6% organic carbon was determined for all sediments collected in Manatee Pocket (Table 2). Total nitrogen levels are also high with an overall mean of 0.38±0.22%. The large range in Al, organic carbon, Si, and $CaCO_3$ content of Manatee Pocket sediments (Table 2) results from a mixture of various quantities of clay, organic matter, sand, and shell. Mean values for organic carbon and nitrogen (Table 2) show that the typical sample is rich in organic matter.

Total sulfur concentrations are also high in sediments from Manatee Pocket as shown for Station H (Fig. 2). Overall, S values for all sediments collected averaged 1.9±1.2% (Table 2). An average C/S ratio of 2.5 was found for Manatee Pocket (Table 2), with values >4 for sediment layers containing obvious plant debris and values <1.5 for sand lenses. Berner (1984) reported a C/S ratio of 2.8 as typical for normal marine sediments. This value results from preservation of roughly constant fractions of organic carbon and reduced sulfur with the amount of labile organic matter limiting the production of iron sulfide. Clearly, abundant levels of both organic carbon and reduced sulfur have been preserved in Manatee Pocket sediments (Fig. 2 and Table 2). With such high sulfur loadings throughout these anoxic, sulfate-reducing sediments, remobilization of such metals as Cd, Cu, Fe, and Zn is less likely because the sulfide phases of these metals have very low solubilities.

TABLE 2. Summary of elemental concentrations in sediments from Manatee Pocket, Florida.

	Manatee Pocket		
Component	Range	Mean ± S.D.	Average Continental Crust[1]
C	0.1–28%	5.5 ± 3.6%	—
N	<0.02–1.2%	0.38 ± 0.22%	—
C/N	7–27	14 ± 3	—
S	<0.1–5.5%	1.9 ± 1.2%	—
C/S	0.8–5.9	2.5 ± 1.2	—
$CaCO_3$	<0.2–30%	6 ± 5%	—
Si	11–44%	25 ± 8%	27.7%
Al	0.02–5.1%	2.4 ± 1.1%	8.2%
Fe	0.07–6.0%	2.4 ± 1.2%	4.1%
Cd	<0.01–1.7 ppm	0.25 ± 0.28 ppm	0.11 ppm
Cu	<1–426 ppm	48 ± 86 ppm	50 ppm
Hg	<0.01–17 ppm	0.58 ± 2.2 ppm	0.05 ppm
Pb	<1–100 ppm	22 ± 21 ppm	14 ppm
Zn	0.4–422 ppm	67 ± 92 ppm	75 ppm

[1] Taylor (1964).

Sediment accumulation rates are difficult to determine in shallow water due to non-steady state accumulation, the presence of sand layers and plant debris, as well as physical and biological mixing of sediments. Lower values for organic carbon and total sulfur, nitrogen, iron, and aluminum that appear periodically downcore (Fig. 2) show the presence of sand layers in these cores. Nevertheless, first-order approximations can be made using geochronometers such as Cs-137 and Pb-210.

At Station H, the Cs-137 signal is undetectable below 40 cm (Fig. 2), a depth roughly equivalent to the early 1950s and the start of atmospheric testing of nuclear weapons. Mixing has distorted any clear maximum in Cs-137 activity that might coincide with the 1963 atmospheric maximum input for Cs-137 (Fig. 2). The trend at Station C is similar (Fig. 2) and a sediment accumulation rate of about 1 cm/y is suggested for cores H and C. In contrast, no detectable Cs-137 is found below 20 cm at Station E (Fig. 2) which is consistent with a recent sediment accumulation rate of about 0.5 cm/y.

At Stations H and C, a linear decrease in the natural logarithm (ln) of excess Pb-210 can be followed downcore until the excess Pb-210 signal has decayed away at about 60 and 110 cm, respectively (Fig. 2). Calculated sediment accumulation rates are 0.5 cm/y for Station H and 0.8 cm/y for Station C. These values are slightly lower than determined from the Cs-137 profiles, suggesting that mixing has somewhat shifted isotope distributions. The presence of various sand and shell layers for Station E and only a short linear trend in excess Pb-210 make accumulation rates by Pb-210 unreliable for this core. Sediments at depths >100 cm in Manatee Pocket most likely date back into the late 1800s. However, we cannot calculate the absolute ages of the oldest sediments because they extend beyond the 100-120 year range of our techniques. Although only speculative at this time, the deeper muck layers represent either long-term natural runoff of organic-rich sediments or a large pulse of natural, organic-rich sediment sometime during the late 1800s.

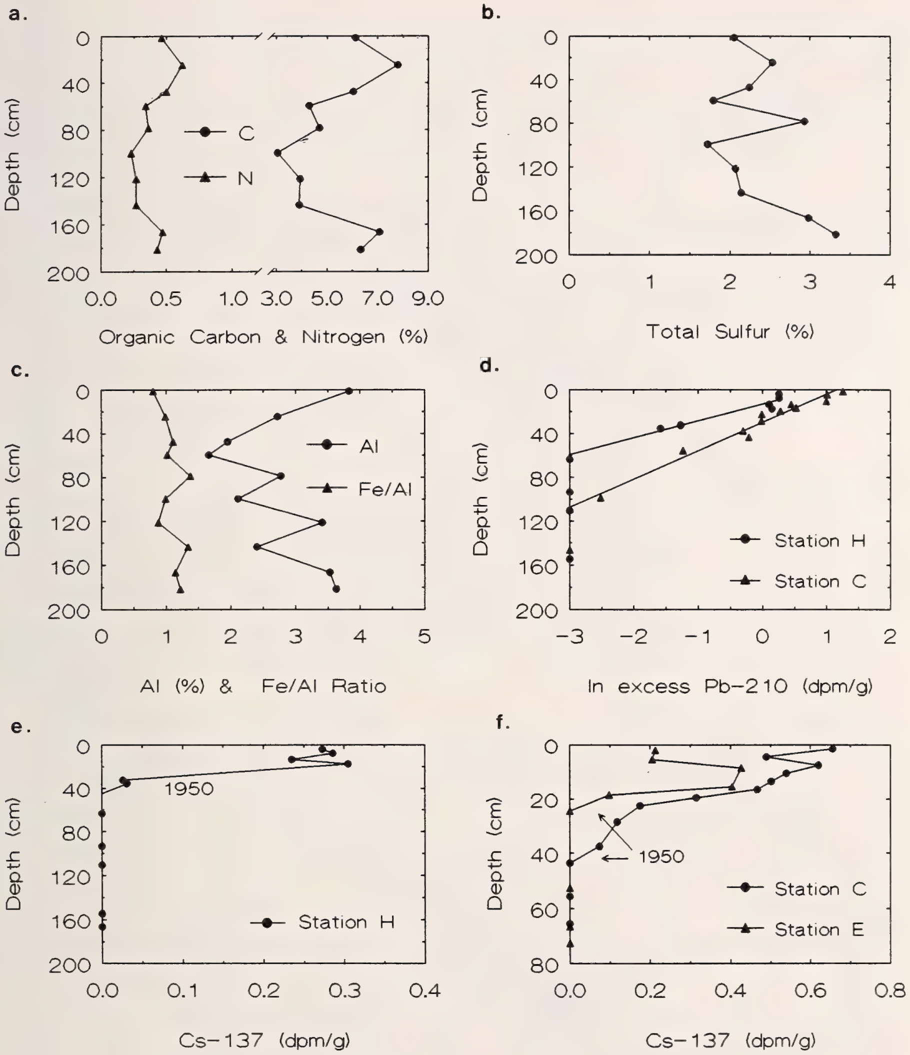
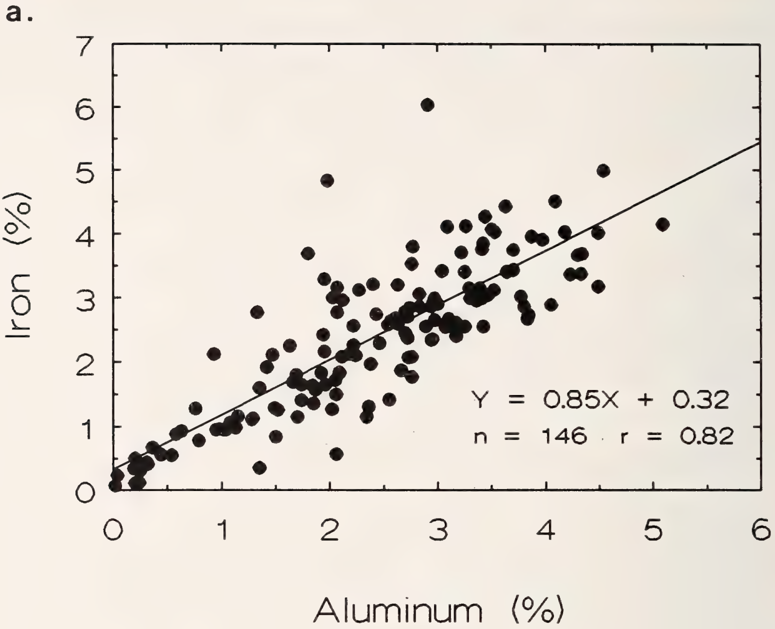


FIG. 2. Vertical profiles of (a) organic carbon and total nitrogen for Station H, (b) total sulfur for Station H, (c) Al and the Fe/Al ratio for Station H, (d) ln excess Pb-210 for sediment cores from Stations H and C, (e) Cs-137 for Station H, and (f) Cs-137 for Stations C and E.

Trace metal contaminants—Concentrations of Al, Cd, Cu, Fe, Hg, Pb, and Zn in surficial sediments from Manatee Pocket vary considerably (Table 2). Lowest values are associated with sandy sediments whereas higher values are typically found with fine-grained, muck deposits. The reasonably good correlation between Fe and Al (Fig. 3) results because both metals are associated with fine-grained aluminosilicate minerals. Iron may be present as a structural component of the aluminosilicates, as an oxide coating, or as a separate sulfide phase. A good correlation also was observed for Fe versus S (Fig. 3).



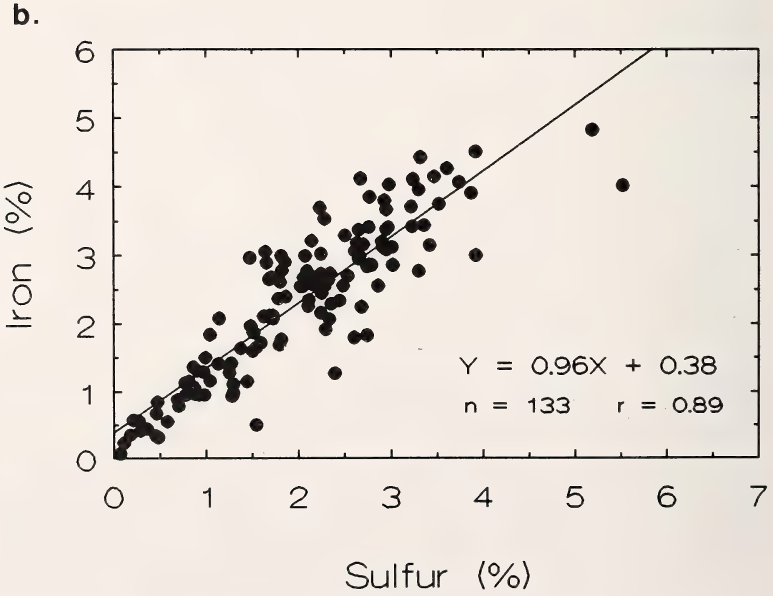


FIG. 3. Scatter plots showing (a) total iron versus total aluminum; and (b) total iron versus total sulfur for sediment samples from Manatee Pocket.

Such overall good correlations among Al, Fe, organic carbon and S occur because contributions of terrestrial organic carbon are accompanied by higher concentrations of Fe and Al in continental detritus (Middelburg, 1991). Furthermore, diagenetic reactions controlled by the decomposition of organic carbon directly influence the reduction of sulfate to sulfide and the formation of abundant iron sulfides.

Under natural conditions, concentrations of many trace metals correlate well with Al and Fe because they too have a strong affinity for fine-grained aluminosilicates. In addition, Al, Fe, and most trace metals are not abundant in quartz sand, carbonate, and most estuarine organic matter; thus, total aluminum and iron concentrations provide a means for normalizing other sediment metal values (Bruland et al., 1974; Trefry and Presley, 1976). Within the State of Florida, Schropp and co-workers (1990) have adopted these approaches to identify metal contamination in sediments.

Sediments are considered to be contaminated with Cu when values for the Cu/Al ratio are greater than background levels and above the 95% prediction interval for the natural Cu/Al ratio (Fig. 4). Nineteen of the 21 surface samples from Manatee Pocket and many of the subsurface samples are contaminated with Cu based on the Florida guidelines. The trend for Hg is similar to that for Cu. All surficial sediments from Manatee Pocket have Pb (Fig. 4) and Zn concentrations that are greater than natural levels based on Pb/Al or Zn/Al ratios.

The historical influx of trace metals was evaluated along a south-north transect across Manatee Pocket as well as downcore by focusing on sites C, E, H, L, and K (Fig. 1). Organic carbon values exceed 4% throughout all of these cores, except in sandy sediments at Station K near the mouth of Manatee Pocket. Highest Zn concentrations are found in the southern end of Manatee Pocket (Station C), with an overall decrease toward the mouth (Fig. 5). A similar spatial distribution was observed for Hg (Fig. 5) and other metals. This trend is consistent with a source of trace metals in upland areas with transport through the main creeks to Manatee Pocket.

Zinc concentrations and Zn/Al ratios are above natural levels in the top 20-60 cm at sites C, E, H, and L (Fig. 5). In deeper sediment layers, background Zn levels and Zn/Al ratios are observed (Fig. 5). It is unlikely that surface enrichment of metals is related to remobilization of the metals in subsurface sediments followed by upward transport and deposition of metals in surficial layers because the total sulfur content is high throughout the core. The onset of Zn contamination is also consistent from site to site. For example, at Stations C and H, elevated Zn levels can be traced to about 40 cm, or the early 1950s. At Station E, the 1950 horizon is at about 20 cm due to a slower rate of sediment accumulation.

The vertical trends described for Zn are similar for Cu, Cd, Hg (Fig. 5), and Pb. Deeper, pre-1950s sediment has natural metal levels, indicating that 70-85% of the total muck is uncontaminated. When metal levels are elevated, the degree of contamination exceeds natural levels by a factor of 5-10. An

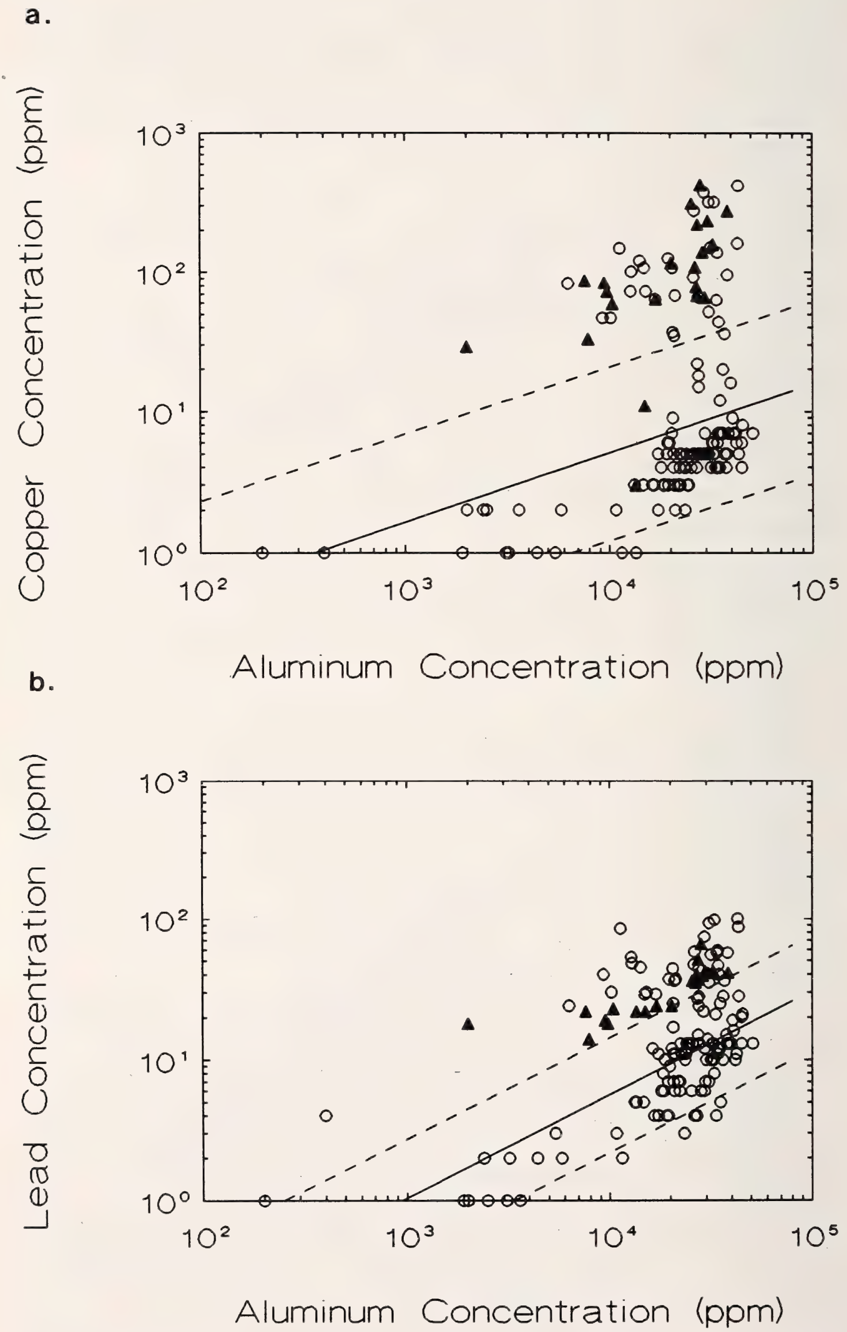


FIG. 4. Scatter plots showing (a) total copper versus total aluminum; and (b) total lead versus total aluminum for sediments from Manatee Pocket. Triangles identify values for surficial sediments (0-2 cm) and open circles show data for subsurface sediments. Solid line shows the linear regression and dashed lines identify 95% prediction intervals.

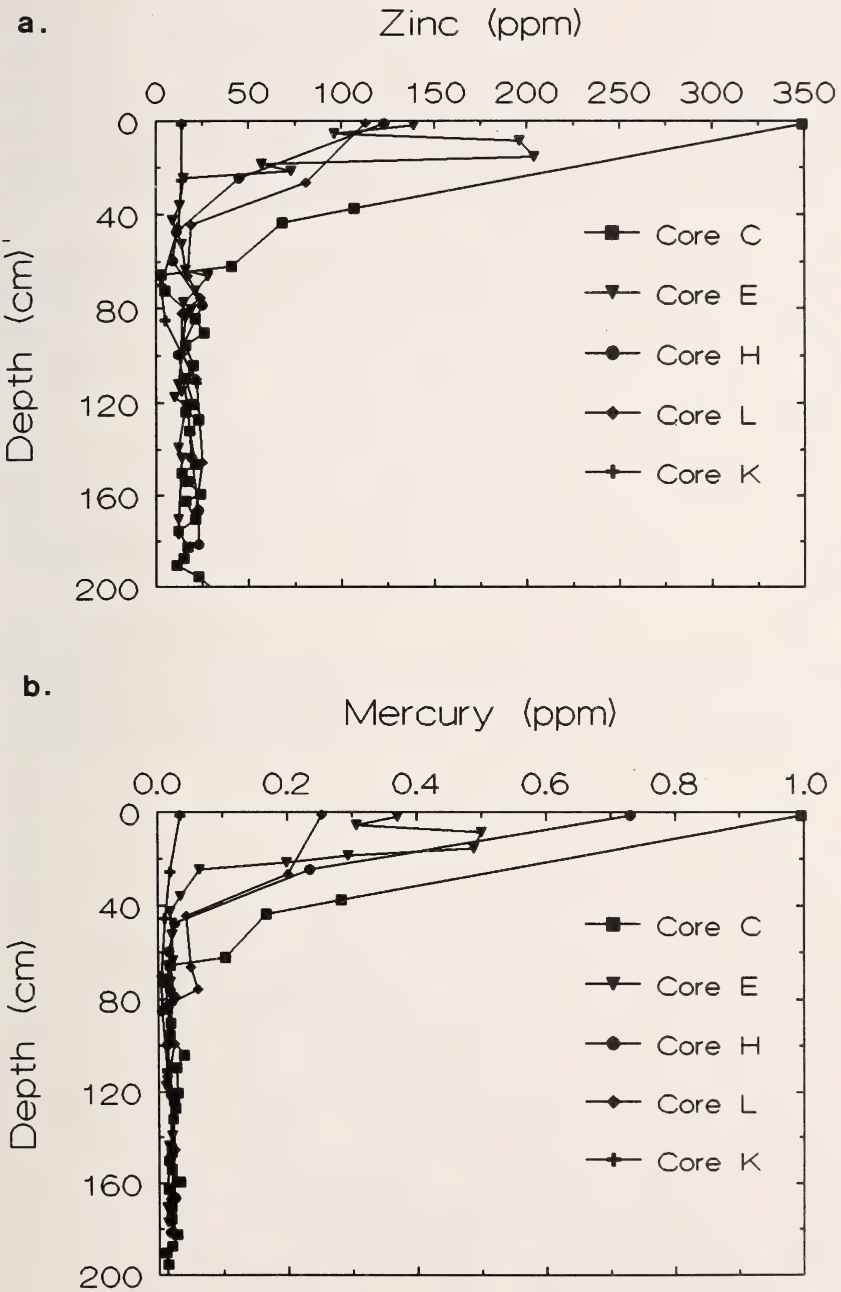


FIG. 5. Vertical profiles for (a) total zinc and (b) total mercury in sediments from Stations C, E, H, L, and K.

exception to the above trend occurs at core site B where concentrations of Hg in the sediments were as high as 17 ppm, at least 200 times greater than natural levels. This incidence of Hg contamination persisted at levels >5 ppm to a depth of 35 cm. No other site has Hg contamination to the same extent, suggesting that the southwest prong of Manatee Pocket is a potential source area. The vertical extent of contamination for Cu, Hg, and Cd is slightly deeper than that for Zn and Pb and suggests that inputs began somewhat before the 1950s.

CONCLUSIONS—Fine-grained, organic-rich, sediments were found at virtually every site in Manatee Pocket. The shape and bathymetry of the pocket effectively trap fine-grained material. Concentrations of organic carbon were as high as 9% with sediments containing >4% organic carbon extending to depths of 100-200 cm in many areas. Vertical profiles for trace metals show contaminant levels only in the top 20-60 cm, which is equivalent to 15-30% of the total length of the muck layer. Thus, a layer of metal-contaminated muck overlies a larger uncontaminated layer. The onset of metal contamination dates to the 1950s for Pb and Zn and somewhat earlier for Cd, Cu and Hg. Prior to the past 40 years, fine-grained, organic-rich sediment accumulated in Manatee Pocket, but without its present-day metal burden.

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LITERATURE CITED

BERNER, R. 1984. Sedimentary pyrite formation: An update. Geochim. Cosmochim. Acta 47:855-862.

BRULAND, K. W., K. BERTINE, M. KOIDE, AND E. D. GOLDBERG. 1974. History of heavy metal pollution in Southern California Coastal Zone. Environ. Sci. Technol. 8:425-432.

CUTSHALL, N. H., I. L. LARSEN, AND C. R. OLSEN. 1983. Direct analysis of ^{210}Pb in sediment samples: self-absorption corrections. Nucl. Instr. Methods 206:309-312.

DAVIS, T. L. 1987. Manatee Pocket and Willoughby Creek water quality survey. Publ. by Florida Department of Environmental Regulation, Port St. Lucie.

FERNALD, E. A. AND D. J. PATTON. 1984. Water Resources Atlas of Florida. Florida State Univ., Tallahassee.

HAUNERT, D. E. 1988. Sediment characteristics and toxic substances in the St. Lucie Estuary, Florida. Technical Pub. 88-10, South Florida Water Management District, West Palm Beach.

MCNULTY, J. AND L. MCNULTY. 1987. Survey to determine bottom sludge depth in Manatee Pocket. Pers. Comm. as an unpublished map, Port Salerno, FL.

MIDDELBURG, J. J. 1991. Organic carbon, sulphur, and iron in recent semi-euxinic sediments of Kau Bay, Indonesia. Geochim. Cosmochim. Acta 55:815-828.

SCHINK, J. C., J. H. STOCKWELL, AND R. A. ELLIS. 1978. An improved device for gasometric determination of carbonate in sediment. J. Sed. Petrol. 48:651-653.

SCHROPP, S. J., F. G. LEWIS, H. L. WINDOM, J. D. RYAN, F. D. CALDER, AND L. C. BURNEY. 1990. Interpretation of metal concentrations in estuarine sediments of Florida using aluminum as a reference element. Estuaries 13:227-235.

TAYLOR, S. R. 1964. Abundance of chemical elements in the continental crust: a new table. Geochim. Cosmochim. Acta 28:1273-1285.

TREFRY, J. H. AND B. J. PRESLEY. 1976. Heavy metals in sediments from San Antonio Bay and the northwest Gulf of Mexico. Environ. Geol. 1:283-294.

__________AND S. METZ. 1984. Selective leaching of trace metals from sediments as a function of pH. Anal. Chem. 56:745-749.

__________, R. P. TROCINE, AND S. METZ. 1989. Quantifying sedimentation and pollution in the lower Hillsborough River. Final report from F.I.T. to the City of Tampa, FL.

__________, S. METZ, R. P. TROCINE, N. IRICANIN, D. BURNSIDE, N. CHEN, AND B. WEBB. 1990. Design and operation of a muck sediment survey. Special Publ. SJ 90-SP3, St. Johns River Water Management District, Palatka, FL.

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ANALYSIS OF HUMAN OSTEOLOGICAL MATERIAL FROM THE BRIARWOODS SITE, FLORIDA

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Abstract: *This paper presents a descriptive and comparative analysis of skeletal remains from the Briarwoods Site (8Pa66), Pasco County, Florida, dated circa A.D. 1000-1500. The fragmentary sample (N=87), included a minimum of 28 males and 11 females for whom sex could be determined. Where age estimation was possible, adults outnumbered juveniles 45 to 12. Stature averaged 158.2 cm (N=4 males). When several sites were compared, sex and adult:subadult ratios, and stature for all sites showed wide variation. At 17.4%, the frequency of pathological lesions or anomalies at Briarwoods was considerably higher than the other burial sites. Adult teeth were characterized by occlusal attrition to the dentin, but no caries.*

Through the analysis of archaeological skeletal remains, one can attempt to reconstruct the demographic profile, dietary pattern, health status, and life-ways of pre-contact Florida Indians (Íscan, 1983; İşcan and Kennedy, 1987; Miller-Shaivitz and İşcan, 1991). Even where only minimal or highly fragmented skeletal material is available, useful information may be obtained by careful analysis and comparison of the remains (Stini, 1985). Further useful information is gained by comparing the osteological characteristics of several populations.

Hrdlička (1922), Snow (1962), Saunders (1972), Shaivitz (1986), and İşcan (1989) published the only major works on the skeletal characteristics of south Florida aborigines. In Hrdlička's case, the article is statistical in nature without any temporal dimension. More recent studies have been limited to those based on fragmentary or disturbed sites (İşcan, 1983; Carr et al., 1984; İşcan and Kennedy, 1987; Maples, 1987; İşcan and Kessel, 1988; Miller-Shaivitz and İşcan, 1991).

This paper presents a descriptive analysis of human skeletal remains from the Briarwoods site, and comparison with six other south Florida archaeological sites.

Materials and Methods—The Briarwoods site (8Pa66) is a small prehistoric sand burial mound excavated in 1980 (Mitchem, 1985). It is located at the northern edge of the Tampa Bay central Gulf coast lowland, two kilometers inland from the coast (Fig. 1). Most remains were found in secondary bundle burials - only two primary burials were uncovered (King, 1981; Gomez and Iscan, 1982; Mitchem, 1985). No associated settlement was found nearby. The site was occupied during the Safety Harbor period (A.D. 1400–A.D. 1513) with what might have been an earlier, Weeden Island component, ca. A.D. 1000-1500 (Mitchem, 1985).

This region contained a larger aboriginal population with whom the Briarwoods inhabitants may have had low intensity contact (Sears, 1960). Remains cannot always be directly linked to a known historic group, and this site may indeed predate the tribal period. Nevertheless, the later occupants may have been the ancestors of the Tocobaga Indians encountered by the Narvaez and De Soto expeditions in the 16th century (Bullen, 1977; Milanich and Fairbanks, 1980).

During excavation, the skeletal material was collected from designated squares, and within each square separate aggregations were isolated. They appear in the collection as individual trays sorted within boxes. These became the aggregation analytic units (White, 1953; Grayson, 1984). To determine the minimum number of individuals (MNI) needed to account for the bones that were recovered from this site, it is necessary to first define the composition of the aggregation (the analytic unit). The next step is to inventory the number of identifiable bone fragments by aggregations and separate them into right and left anatomical components. Once each side is counted, the highest figure becomes the MNI.

Assessment of sex, age, and stature followed standard osteological techniques (Krogman and Íşcan, 1986). In the absence of epiphyses, pubic symphyses, and ribs, age for the most part was estimated from tooth eruption and dental wear (Stewart, 1979; Brothwell, 1981; Lovejoy, 1985; Ubelaker, 1989). Calculation of stature was possible in only four instances using sector regression formulae (Genovés, 1967; Steele and McKern, 1969, Steele, 1970). Anomalies and pathological lesions were diagnosed based on published criteria (Dahlberg, 1971; Kovaks, 1971; El-Najjar and McWilliams, 1978; Morse, 1978; Ortner and Putschar 1981; Isler et al., 1985; Lovejoy, 1985; Bass, 1987).

The data thus derived were then compared demographically and osteometrically with other south Florida populations. These include the Boynton Beach Mound (BB), Palm Beach County, 150 B.C. to contact (Íşcan and Kessel, 1988); Fort Center (FC), Glades County, Okeechobee Basin major ceremonial center and mortuary site, pre-450 B.C.—contact (Sears, 1982; Miller-Shaivitz and Íşcan, 1991); Margate-Blount (MB), Broward County, ceremonial complex, post Archaic to contact (Íşcan, 1983); Bayshore Homes (BH), Hillsboro County, A.D. 1000–A.D. 1300, secondary burials (Sears, 1960; Snow, 1962); Republic Groves (RG), Hardee County, Late Archaic, 2000 B.C. (Saunders, 1972; Wharton et al., 1981); Gautherie (GA), Brevard County, near Cocoa Beach, primary Archaic sand burials, 2353 B.C. and primary intrusive marl burials, A.D. 387 (Maples, 1987) (Fig. 1).

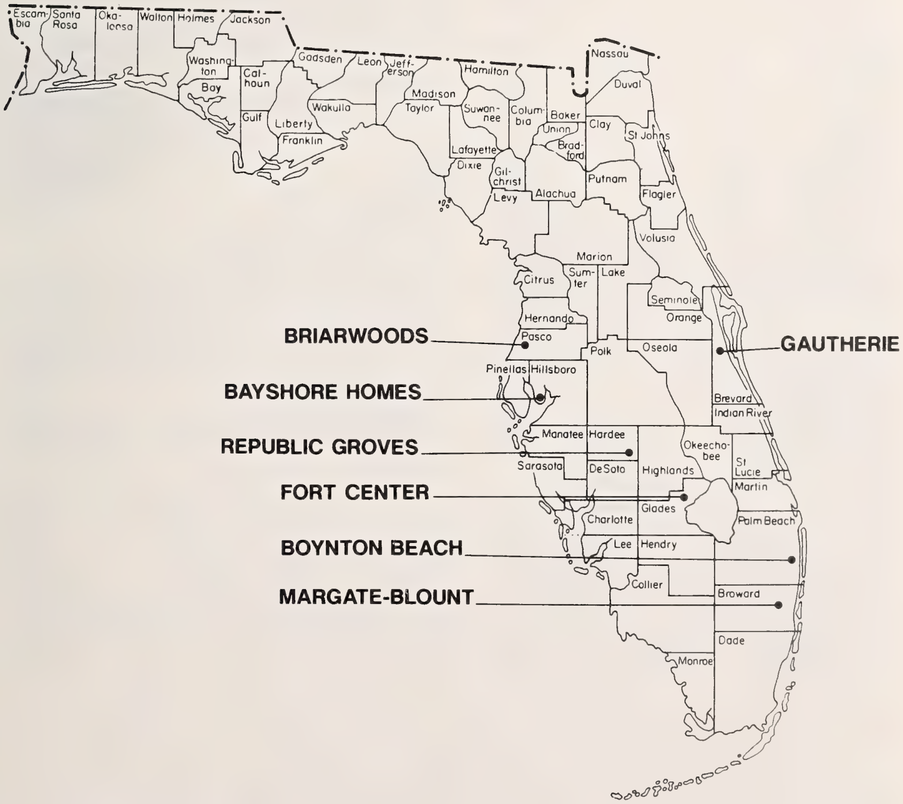

FIG. 1. Briarwoods Site location relative to the six other sites.

RESULTS—Assessment of minimum number of individuals of the skeletal material yielded a count of 87 individuals in this sample. Some were represented by only one deciduous tooth or a bone fragment such as a mastoid process.

Because of the fragmentary nature of the sample, less than half (39) of the 87 individuals could be sexed. Of those, 28 were judged to be male (32%) and 11, female (13%). Of the 57 individuals for whom age was estimated, 45 were adults (52%) and 12 were subadults (14%). This yielded an adult:subadult ratio of 3.8:1. At the other sites (Table 1), the ratios ranged from a high of 5.4:1 at Fort Center to a low of 1.2:1 at Gautherie intrusive (Sears, 1982; Maples, 1987; Miller-Shaivitz and Íşcan, 1991). Stature could be calculated for four males and they averaged 158.2 cm. This value is less than most other Florida samples (Table 1).

TABLE 1. Comparison by sex, age, and stature (cm) of the Briarwoods (BW) inhabitants with six other prehistoric Florida burial populations.*

	BW	BB	FC	MB	BH	RG	GA	
							Arch.	Intr.
N=	87	35	64	49	36	19	105	26
Sex								
Male	28	8	33	20	16	10	25	9
Female	11	16	31	22	20	9	40	11
Indeter.	48	11	—	7	—	—	40	6
Age								
Subadult	12	7	10	11	—	—	48	12
Adult	45	17	54	48	—	—	57	14
Indeter.	30	11	—	—	—	—	—	—
Stature								
N=	4	—	4	4	33	—	3	1
Male	158.2	—	164.4	169.8	168.9	—	164.7	168.1
N=	—	—	2	3	28	—	5	5
Female	—	—	156.0	(161.8)	164.0	—	154.3	156.9

*BB, Boynton Beach Mound; FC, Fort Center; MB, Margate-Blount; BH, Bayshore Homes; RG, Republic Groves; GA, Gautherie.

Many individuals showed pathological conditions and morphological anomalies (Fig. 2). A more complete report of the pathological cases is being prepared separately (Íşcan et al., n.d.). The bones of twelve individuals (10.4%) exhibited evidence of animal gnawing (Fig. 2a). One individual had an abscess at the alveolar margin (Fig. 2c). A tibia shows reactive bone growth suggesting periostitis (Fig. 2c). The cranial vault in one specimen displayed diagonal asymmetry and Wormian bones in the right lambdoidal suture (Fig. 2d). Fig. 2f reveals another case of tibial periostitis. All nine individuals with incisors exhibited "shoveling," and three (3.4%) of these were double-shovel shaped (Fig. 2f). Other conditions include a tibia with periostosis in the medullary cavity accompanied by cortical thickening (Fig. 2g) and endostosis of the ulna with occlusion of the medullary cavity (Fig. 2h). As reported by Íşcan and Gomez (1982), the calotte of specimen No. 52 was suggestive of Paget's disease.

The teeth were notable for extensive attrition. Many were worn horizontally to the dentin. On the other hand, there was no evidence of caries, interproximal grooving, or dental enamel hypoplasia.

Discussion and Conclusion—Since 1983, when Íşcan and Miller-Shaivitz (1983) noted that information on the skeletal biology and health of

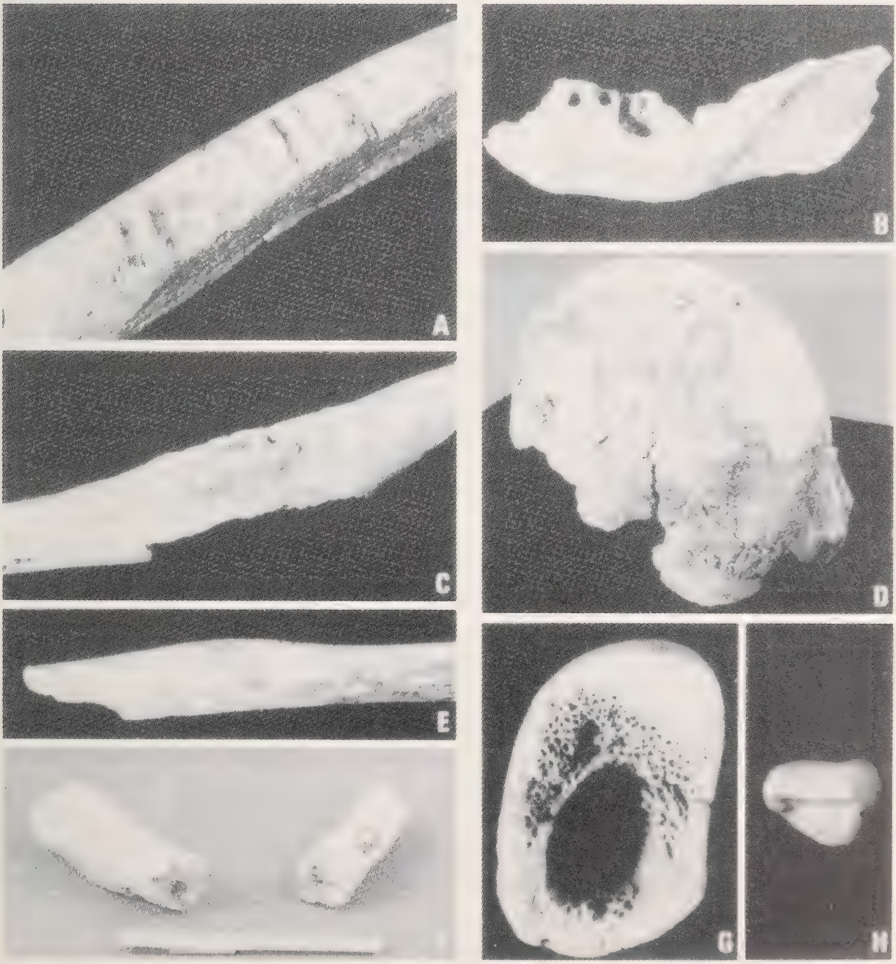

FIG. 2. Examples of pathological lesions and other conditions. (a) Tooth marks from animal gnawing of right femur. (b) Abscess at alveolar margin of left mandible. (c) Reactive bone area in midshaft of right tibia, suggesting periostitis. (d) Cranial vault, asymmetrical diagonally. (e) Tibia with periostitis of unknown etiology. (f) Endostosis with occlusion of medulary cavity of an ulna. (g) Transverse section of diaphysis of right tibia showing periostosis in medulary cavity and cortical thickening. (h) Double shovel-shaped maxillary central incisor with serrated occlusal edge.

prehistoric Florida Indians consisted of only a handful of monographs, a few more have been added allowing broader comparisons (Table 1). The high ratio of males to females (1.6:1) at this site contrasts with other south Florida sites which range from 1.1:1 to 0.5:1 . Obviously, there is potential for misinterpretation of the data which can derive from a number of factors. Errors in determining sex can occur due to variations in the degree of preservation and the fragmentary nature of the sample. Furthermore, Weiss (1972) cautions that he has uncovered a 12% bias in favor of males when sexing from skeletal material. Also, there have been differential burial practices over the 500 year span reported for this burial site. Moreover, in preliterate societies, males generally lived longer than females; the reverse is true of contemporary industrialized societies (Angel, 1969; Stini, 1985). Finally, although, one can not rule out culturally related female infanticide and neglect when there is an excess of mature males (Stini, 1985), there is no evidence of this in prehistoric south Florida.

The adult:subadult ratio of 45:12 in this group was consistent with the overall averages for the other sites. It should be noted that, because of the limitations of the skeletal material, 86% of the age estimates were based on dentition.

The most notable feature of the skeletal material from the Briarwoods site was the high incidence of pathological lesions and anomalies. Another interesting observation was the number of bones with animal gnawing. This suggests they may have been exposed for some time before burial, and supports the archaeological report of bundle burials and early explorers' accounts of the use of charnel houses to store bones for later mass burial (Milanich and Fairbanks, 1980; Sears, 1982).

Dentition also is an important indicator of diet and environmental conditions. The extensive attrition may reflect the gritty shellfish diet known to have been a substantial part of the coastal Indians' food resources (Ísler et al., 1985). The absence of dental enamel hypoplasia may indicate a lifestyle with little seasonal dietary stress. Shovel shaped incisors are found in high frequency in Mongoloids, especially American Indians (Carbonell, 1963). It has been suggested that shoveling was a biological adaptation that served to strengthen the tooth (Dahlberg, 1963). This trait is found with diminishing frequency in modern Mongoloid populations (Hrdlička, 1920). This decrease may result from a relaxation in selection pressures brought about by culturally based changes in food preparation which reduced the adaptive advantage of shoveling (Calcagno, 1989).

In all, the dental characteristics were consistent with a hunting-gathering-fishing subsistence economy (Isler et al., 1985). This mirrored similar findings among Indians of the California coast (Walker, 1983). A diet of meat and fish, rather than cereals is further sustained by spectrographic analysis of trace elements in archaeological skeletal material of coastal and inland south Florida populations (Íşcan et al., 1989). The absence of significant differences in trace elements in the bones that distinguish the dietary practices of hunters from those who depended on horticultural products, corroborates an inference that the pre-contact Indians in south Florida were seasonally migratory with little change in subsistence activity from Archaic times to European contact (İşcan et al., 1989).

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LITERATURE CITED

Angel, J. L. 1969. The bases of paleodemography. Am. J. Phys. Anthropol. 30:427-437.

Bass, W. M. 1987. Human Osteology: A Laboratory and Field Manual of the Human Skeleton. Special Pub. No. 2, Missouri Archaeol. Soc., Columbia, MO.

Brothwell, D. R. 1981. Digging Up Bones: The Excavation, Treatment, and Study of Human Skeletal Remains. Cornell University Press, Ithaca, NY.

Bullen, R. P. 1977. Tocobaga Indians and the Safety Harbor culture. Pp. 50-58. *In:* MILANICH J.T. AND S. PROCTOR (eds.). Tacachale: Essays on the Indians of Florida and Southeastern Georgia During the Historic Period. University Presses of Florida, Gainesville, FL.

Calcagno, J. M. 1989. Mechanisms of Human Dental Reduction. Univ. of Kansas Publications in Anthropology, 18, Lawrence, KS.

Carbonell, V. 1963. Variations in the frequency of shovel-shaped incisors in different populations. Pp. 211-234. *In:* Brothwell, D. R. (ed.), Dental Anthropology. Pergamon Press, New York, NY.

Carr, R., M. Y. İşcan, and R. A. Johnson. 1984. A late archaic cemetery in south Florida. Florida Anthropol. 37:172-188.

Dahlberg, A. A. 1963. Analysis of the American Indian dentition. Pp. 149-178. *In:* Brothwell, D. R. (ed.), Dental Anthropology. Pergamon Press, New York, NY.

_________. 1971. Dental Morphology and Evolution. Univ. Chicago Press, Chicago. IL.

El-Najjar, M. Y. and K. R. McWilliams. 1978. Forensic Anthropology. Charles C. Thomas, Springfield, IL.

Genovés, S. C. 1967. Proportionality of long bones and their relation to stature among Mesoamericans. Am. J. Phys. Anthropol. 26:67-78.

Gomez, J. and M. Y. İşcan. 1982 Analysis of human skeletal remains from Pasco County. Abstract, Florida Scient. 45 (Suppl. 1):13.

Grayson, D. K. 1984. Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas. Academic Press, Orlando, FL.

Hrdlička, A. 1920. Shovel-shaped teeth. Am. J. Phys. Anthropol. 3:429.

_________. 1922. The Anthropology of Florida. Fla. State Historical Society Pub. No. 1, Deland, FL.

İşcan. M. Y. 1983. Skeletal biology of the Margate-Blount population. Florida Anthropol. 36(3-4):154-166.

_________. 1989. Odontometric profile of a prehistoric southeastern Florida population. Am. J. Phys. Anthropol. 78:3-8.

_________J. Burken, and M. H. Kessel. (n.d.) Paleopathology of the Briarwoods Site people. Unpublished manuscript. Florida Atlantic Univ., Boca Raton, FL.

_________and J. Gomez. 1982. Prehistoric Paget's disease from Florida. Abstract, Florida Scient. 45 (Suppl. 1):13.

_________and W. J. Kennedy. 1987. Osteological analysis of human remains from the Nebot Site. Florida Scient. 50(3):147-155.

_________and M. H. Kessel. 1988. Osteology of the prehistoric Boynton Beach Indians. Florida Scient. 51(1):12-18.

_________M. H. Kessel, and S. Martis. 1989. Spectrographic analysis of trace elements in archaeological skeletal material from Florida: A preliminary report. Am. J. Phys. Anthropol. 79:483-488.

_________and P. Miller-Shaivitz. 1983. A review of physical anthropology in the Florida

Anthropologist. Florida Anthropol. 36:114-123.

Isler, R. J. Schoen, and M. Y. İşcan. 1985. Dental pathology of a prehistoric human population in Florida. Florida Scient. 48(3):129-139.

King, J. M. 1981. A qualitative field method for determining the presence of phosphorus in soils. Florida Anthropol. 34:156-163.

Kovaks, I. 1971. A systematic description of dental roots. Pp. 211-256. *In:* A. A. Dahlberg, (ed.). Dental Morphology and Evolution. Univ. Chicago Press, Chicago, IL.

Krogman, W. M. and M. Y. İşcan. 1986. The Human Skeleton in Forensic Medicine. Charles C. Thomas, Springfield, IL.

Lovejoy, C. O. 1985. Dental wear in the Libben population: Its functional pattern and role in the determination of adult skeletal age at death. Am. J. Phys. Anthropol. 68:47-56.

Maples, W. R. 1987. Analysis of Skeletal Remains Recovered at the Gauthier Site, Brevard County, Florida. Miscellaneous Project Report Series No. 31. Florida State Museum, Department of Anthropology, Gainesville, FL.

Milanich, J. T. and C. H. Fairbanks. 1980. Florida Archaeology. Academic Press, Orlando, FL.

Miller-Shaivitz, P., and M. Y. İşcan. 1991. The prehistoric people of Fort Center: Physical and health characteristics. Pp. 131-147. *In:* Powell, M. L., P. S. Bridges, and A. M. W. Mires (eds.). What Mean These Bones? Studies in Southeastern Bioarchaeology. Univ. Alabama Press, Tuscaloosa, AL.

Mitchem, J. M. 1985. Excavation of the Briarwoods Site (8Pa66), Pasco County, Florida. Florida Scient. 48(3):161-165.

Morse, D. 1978. Ancient Disease in the Midwest. Illinois State Museum Reports of Investigations, No. 15, Illinois State Museum, Springfield, IL.

Ortner, D. J. and W. G. J. Putschar. 1981. Identification of Pathological Conditions in Human Skeletal Remains. Smithsonian Institution Press, Washington, D.C.

Saunders, L. P. 1972. Osteology of the Republic Groves Site. Masters thesis, Florida Atlantic Univ., Boca Raton, FL.

Sears, W. H. 1960. The Bayshore Homes Site, St. Petersburg, Florida. Contributions of the Florida State Museum, No. 6. Univ. Florida, Gainesville, FL.

_________. 1982. Fort Center: An Archaeological Site in the Lake Okeechobee Basin. Univ. Presses of Florida, Gainesville, FL.

Shaivitz. P. 1986. Physical and Health Characteristics of the Prehistoric Indians from the Fort Center Site. Masters thesis, Florida Atlantic Univ., Boca Raton, FL.

Snow, C. E. 1962. Indian Burials from St. Petersburg, Florida. Contributions of the Florida State Museum, 8. Univ. of Florida, Gainesville, FL.

Steele, D. G. 1970. Estimation of stature from fragments of long limb bones. Pp. 85-97. *In:* Stewart, T. D. (ed.), Personal Identification in Mass Disasters. National Museum of Natural History, Smithsonian Institution, Washington, D.C.

_________and T. W. McKern. 1969. A method for assessment of maximum long bone length and living stature from fragmentary long bones. Am. J. Phys. Anthropol. 31:215-228.

Stewart, T. D. 1979. Essentials of Forensic Anthropology: Especially as Developed in the United States. Charles C. Thomas, Springfield, IL.

Stini, W. A. 1985. Growth rates and sexual dimorphism in evolutionary perspective. Pp. 191-226. *In:* Gilbert, R. I. and J. H. Mielke (eds.). The Analysis of Prehistoric Diets. Academic Press, Orlando, FL.

Ubelaker, D. H. 1989. Human Skeletal Remains: Excavation, Analysis, Interpretation. Aldine Publishing Co., Chicago, IL.

Walker, P. L. 1983. Prehistoric California Indians. Abstract, Paleopathology Assn. Papers on Paleopathol.:4-5.

Weiss, K. M. 1972. On the systematic bias in skeletal sexing. Am. J. Phys. Anthropol., 37:239-250.

Wharton, B. R., G. R. Ballo, and M. E. Hope. 1981. The Republic Groves Site, Hardee County, Florida. Florida Anthropol. 34:58-80.

White, T. E. 1953. A method of calculating the dietary percentages of various food animals utilized by aboriginal peoples. Am. Antiquity, 18:396-398.

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THE NON-MARINE HERPETOFAUNA OF EGMONT KEY, HILLSBOROUGH COUNTY, FLORIDA,

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ABSTRACT: *We observed ten amphibian and reptile species between January 1990 and April 1991 on Egmont Key, Hillsborough County, Florida. Four additional species* (Anolis carolinensis, Cnemidophorus sexlineatus, Sceloporus undulatus, Scincella lateralis) *are known only from museum specimens collected in 1869-1870 and 1904 and are thought to be extirpated, possibly as a result of predation by feral cats. The possible origins of the island's herpetofauna are discussed.*

EGMONT Key is a small isolated island situated at the mouth of Tampa Bay, approximately 50 km southwest of Tampa and 32 km south of St. Petersburg (parts of sections 24, 25, and 26, T.33S, R.15E), in Hillsborough County, Florida. The 180-ha island is over 2 km from the nearest accessible landfall at Ft. Desoto (Mullet Key, Pinellas County) and is separated from the mainland by the Egmont and Southwest channels. Egmont Key is a National Wildlife Refuge and was recently leased to the State of Florida by the U. S. Fish and Wildlife Service for use as a state park. In preparation for the establishment of Egmont Key State Park, the Florida Park Service (FPS) requested that we conduct an inventory of the island's herpetofauna.

The following species were recorded from Egmont Key during 11 days in January 1990, and February, March, and April 1991: *Gastrophryne carolinensis, Hyla squirella, Terrapene carolina bauri, Gopherus polyphemus, Anolis sagrei, Eumeces inexpectatus, Elaphe obsoleta quadrivittata, Lampropeltis getula,* and *Crotalus adamanteus.* Park rangers also have observed the presence of *Coluber constrictor priapus* (Baker, 1990), although we failed to locate this snake during our surveys. A search of museum collections revealed the following specimens from Egmont Key: *Scincella lateralis (*FMNH 2987*),* *Sceloporus undulatus undulatus* (FMNH 2986), *Anolis carolinensis* (FMNH 2988, YPM 1312), *Cnemidophorus sexlineatus* (FMNH 2983, YPM 1388), *Eumeces inexpectatus* (FMNH 2984), and *Coluber constrictor* (YPM 131). The list of two amphibians and 12 reptiles represents approximately 17% of the local non-marine herpetofauna (81 species) from adjacent mainland areas in Hillsborough, Manatee, and Pinellas counties.

The earliest collections from Egmont Key were given to the Peabody Museum of Natural History (YPM) by William T. Coons in 1869-1870 (Sibley, 1990). The Field Museum of Natural History (FMNH) collections were made by Dr. Louis Stengel in 1904 and transmitted to this institution by Henry Ramstadt in 1919 (Resetar, 1990). No other information is available concerning these collections or the collectors.

Our frog records are based on isolated individuals found away from water and from occasional "rain-call" vocalizations by *Hyla squirella*. We were not present during periods of breeding, but we presume that frogs reproduce in water that accumulates in the drainage ditches that criss-cross the island, a large swale at the south end of the island, gun implacements, the old ice house and other buildings associated with abandoned Fort Dade, or in cisterns on the Pilot's Association Compound.

The exceptionally large colony of *G. polyphemus* was previously noted by Logan (1979) and McCoy and Mushinsky (1992). They estimated the population to be in excess of 1500 and 2100 tortoises, respectively. Our survey also revealed a large population of *T. carolina* that apparently has escaped previous detection. In January, March, and April 1991, we marked 215 individuals as part of a study to monitor long term trends in Egmont's box turtle population. Most turtles were marked on the southern half of the island, although the species occurs island-wide.

Recent records for other species were obtained through incidental sightings while surveying for box turtles. We encountered individuals of *Lampropeltus getula* and *Crotalus adamanteus* in dense cabbage palm (*Sabal palmetto*)-Brazilian pepper (*Schinus terebinthifolius*) thickets, although both species have been observed by park rangers on the pilot's compound. Interestingly, two color morphs of *L. getula* (yellow south Florida-like form and a dark chain kingsnake-like form) have been encountered. Several *Elaphe obsoleta quadrivittata* (typical yellow rat snake morph) were found at night either crossing the brick roads or in palm trees along these roads. Representative individuals of these three snakes were photographed and released. Occasional specimens of *E. inexpectatus* were encountered under scrap wood in trash piles in back of the pilot's compound, whereas *A. sagrei* was abundant throughout the entire island.

The isolation of the island at the edge of Tampa Bay and the Gulf of Mexico raises questions concerning the fauna's origins and its survival through periods of severe weather and human disturbance. Hurricanes have repeatedly struck the island. One particularly powerful storm in September 1848 carried a storm tide across the island which destroyed the lighthouse and brought water "...over the window sills" of the brick lighthouse keeper's dwelling (Grismer, 1950). Additional strong hurricanes struck the island in 1848 (second storm in November), 1921, 1926, and 1935 (Grange, 1977). In addition to the 19th century lighthouse, Egmont Key was a staging area for Seminole Indians prior to their removal to Arkansas following the Third Seminole War, a Confederate installation during the Civil War until captured by Union forces in 1861, Spanish American War fort (Fort Dade, established in 1898, deactivated in 1921), and the headquarters for the Tampa Bay Pilot's Association (boat pilots who guide cargo vessels in and out of the port of Tampa) since 1912 (Grange, 1977; Stafford, 1980; Sarles, 1960). With the construction of Fort Dade consisting of over 70 buildings, a sophisticated sewer system, cisterns, wells, brick streets and sidewalks, much of the island was deforested. At least some of the buildings were surrounded by lawns, and palm trees lined the main sidewalks (Stafford, 1980). Soldiers stationed on Egmont Key complained about mosquitoes, rattlesnakes, and the tropical climate (Stafford, 1980).

Unfortunately, there is no record of the island's pre-settlement biota, except for the brief description "...surrounded on all sides by a smooth beach, and is mostly, first rate cabbage hammock and prairie with no mangrove" (from survey notes of J. R. Apthrop, dated 21 February 1876), the complaint of soldiers concerning rattlesnakes (Stafford, 1980), and the few museum specimens obtained by Coons in 1869-1870 (YPM specimens) and Stengel in 1904 (FMNH specimens). There are no vertebrate fossil deposits (Morgan, 1990) or prehistoric Indian midden sites known from the island (Grange, 1977).

The origin of the Egmont Key herpetofauna is open to speculation. The presence of at least three species of reptiles in 1869-1870 shows that certain elements of the herpetofauna were on Egmont Key prior to the establishment of Fort Dade. The second collection was made when Fort Dade was occupied by as many as 300 people. The latter collection duplicated two of three species (*A. carolinensis, C. sexlineatus*) from Coons' collection and added three other species (*S. lateralis, S. undulatus,* and *E. inexpectatus*). *Coluber constrictor* was the only species that Coons collected that was not recollected in 1904. The absence of such visible species as *G. polyphemus* and *T. carolina* in these early collections suggests either that collectors purposedly neglected to obtain specimens or that populations of these species were lower than at present or did not occur on the island at all. We failed to collect four (*A. carolinensis, C. sexlineatus, S. undulatus, and S. lateralis)* of the six species reported by earlier collections and suspect that they were extirpated by domestic cats brought to the island by the boat pilots. However, the introduction of the exotic *A. sagrei* may have played some role in the exclusion of the native *A. carolinensis.* This species apparently arrived after its introduction to the Tampa area, probably via boat traffic between Tampa and the island. The first museum specimens of *A. sagrei* from the Tampa Bay area were obtained in 1947, although the species probably had been in the area for at least four to five years prior to these collections (Oliver, 1950). Today, the species is well established in the bay region.

Many other Egmont Key species are also good candidates for passive transport since they frequently occur around human activities and could pass unnoticed on construction materials sent to the island. The presence of *Gopherus* and *Terrapene* is more difficult to explain, although founder individuals could have succeeded in crossing from the mainland where they were abundant in the past. Alternatively, island residents could have intentionally transported them to the island. The presence of the venomous *Crotalus adamanteus* probably cannot be explained by human-mediated dispersal. This species is well-known for colonizing coastal islands, particularly in Florida (Allen and Slatten, 1945; Conant and Bridge, 1939; Klauber, 1949, 1956; Neill, 1958) and is likely to have crossed over saltwater to reach them, particularly in light of an account by E. Ross Allen who saw an eastern diamondback rattlesnake swimming in the open sea 35 km off Tampa (Neill, 1958).

Similarly, the flora of the island has undergone obvious changes in the last

150 years primarily because of the island's human history. Although components of the original cabbage palm hammock and prairie vegetation remain, most of the original vegetation was removed with the construction of Fort Dade. The island has been invaded extensively by exotic plants, particularly sisal (*Agave sisalana*), Spanish dagger (*Yucca aloifolia*), brazilian pepper and Australian pine (*Casuarina equisetifolia*). The agave and Spanish dagger appear to have been introduced as ornamentals when the fort was constructed. David W. Hall, in a recent plant survey of Egmont Key, reported that 11 percent of the 130 species of flora consisted of exotic species (FPS, unpubl. data).

The faunas of most Florida barrier and offshore islands are still poorly known, and there are virtually no records prior to European settlement. Our observations on Egmont Key suggest that substantial faunal changes have occurred as a result of human activities. The present faunas of other coastal islands also probably do not mirror past distributions or compositions. Attempts to characterize, protect, and manage the few remaining undeveloped Florida islands will be hampered by a lack of adequate museum material and historical documentation of human activities. We believe that immediate surveys should be initiated to describe the biological diversity of Florida's nearshore islands as a prerequisite to the wise conservation of these little known habitats.

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LITERATURE CITED

ALLEN, E. R. AND R. SLATTEN. 1945. A herpetological collection from the vicinity of Key West, Florida. Herpetologica 3:25-26.

BAKER, R. H. 1990. Florida Park Service, Egmont Key, FL. Pers. Comm.

CONANT, R. AND W. BRIDGES. 1939. What Snake Is That? D. Appleton-Century Co., Inc. NY, 163 pp.

GRANGE, R. T., JR. 1977. An archaeological survey of Egmont Key National Wildlife Refuge, Hillsborough County, Florida. Unpubl. report, U.S. Fish and Wildlife Service.

GRISMER, K. H. 1950. Tampa. A History of the City of Tampa and the Tampa Bay Region. St. Petersburg Printing Co., Inc.

KLAUBER, L. M. 1949. Some new and revised subspecies of rattlesnakes. Trans. San Diego Soc. Nat. Hist. 11(6): 61-116.

_________1956. Rattlesnakes: Their Habits, Life Histories, and Influences on Mankind. 2 vols. Univ. California Press, Berkeley., 1476 pp.

LOGAN, T. 1979. Survey of gopher tortoises (*Gopherus polyphemus*) populations of federal lands in Florida. Unpubl. report, U.S. Fish and Wildlife Service.

McCoy, E. D. and H. R. Mushinsky. 1992. Studying a species in decline: Changes in populations of gopher tortoises on federal lands in Florida. Fla. Scientist. 55 (2): 116-125.

Morgan, G. 1990. Florida Museum of Natural History, Gainesville, FL. Pers. Comm.

Neill, W. T. 1958. The occurrence of amphibians and reptiles in saltwater areas, and a bibliography. Bull. Marine Sci. 8(1):1-97.

Oliver, J. A. 1950. *Anolis sagrei* in Florida. Copeia 1950(1): 55-56.

Resetar, A. 1990. Field Museum of Natural History, Chicago, IL. Pers. Comm.

Sarles, F. B., Jr. 1960. Historic sites report on Fort Desoto Park, Pinellas County, Florida. Unpubl. report., National Survey of Historic Sites and Buildings, National Park Service, Virginia.

Sibley, F. C. 1990. Peabody Museum of Natural History, New Haven, CT. Pers. Comm.

Stafford, J. W. 1980. Egmont Key: Sentinel of Tampa Bay. Tampa Bay History 2(1): 15-29.

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THE ABSENCE OF FORMATION OF NITROSOAMINES UNDER ENVIRONMENTALLY SIMULATED CONDITIONS

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Abstract—*Studies of water chemistry in the Hillsborough River led to an examination of the factors that might lead to production of nitrosoamines under environmentally simulated conditions in the laboratory. Nitrosoamines were determined by means of a chemiluminescence-based technique providing determination of nitrosoamine plus nitrite concentrations. Subtraction of nitrite ion concentration gave total nitrosoamine concentrations. The components of the study system consisted of nitrate -nitrogen (70 ppb), Hillsborough River sediment, and chelated-copper herbicide (a commercially available ethanolamine derivative, 4 ppm), adjusted to pH 6.6 in aqueous phase. Nitrosoamine production was not observed at 25°C after about 10 days when all three components were present. No nitrite nor nitrosoamine formation was noted, or was below the sensitivity of the method (0.1 ng/sample), when chelated-copper was not present, when nitrate was not added to the system, or in the absence of sediment. The results indicate that the use of this chelated-copper herbicide does not lead to the formation of nitrosoamine under environmentally simulated conditions.*

Nitrosoamines can cause cancers, mutations and birth defects in lab animals (Druckrey et al., 1967). Meyers and Hendricks (1982) reported that several nitrosoamines caused cancers in fish. Since nitrite and certain amines present in the aquatic environment form nitrosoamines (Abidi et al., 1986), we examined a common copper-containing herbicide, bis(ethanolamine)copper(II) ion for its potential to engage in a similar reaction. Bis(ethanolamine)copper(II) ion, trade name Cutrine-plus, together with copper(II) sulfate pentahydrate is extensively used as a herbicide to treat aquatic plants in Florida waters. For example, over a 3-month period, one 167-acre area of the Hillsborough River in Tampa received as much as 30,000 lbs. of $CuSO_4$ and 65 gallons of Cutrine-plus, the equivalent of 50 lbs. of the copper-chelate (Gianatasio, 1990). The application area is shown (Fig. 1) between 40th and 30th Streets (stations 6 to 7).

The environmental fate of these copper chemicals with respect to their mobility, their persistence in the environment, and possible harmful effects of their use is being studied in our laboratory. Previous experiments indicated an absence of nitrosoamines in the water column (Braman et al., 1990), but they appeared to be formed in the presence of nitrate, sediment and Cutrine-plus. The present study involves looking at sediment samples to determine primarily whether the chelating agent reacts with nitrate in the presence of sediment bacteria to produce nitrosoamines.

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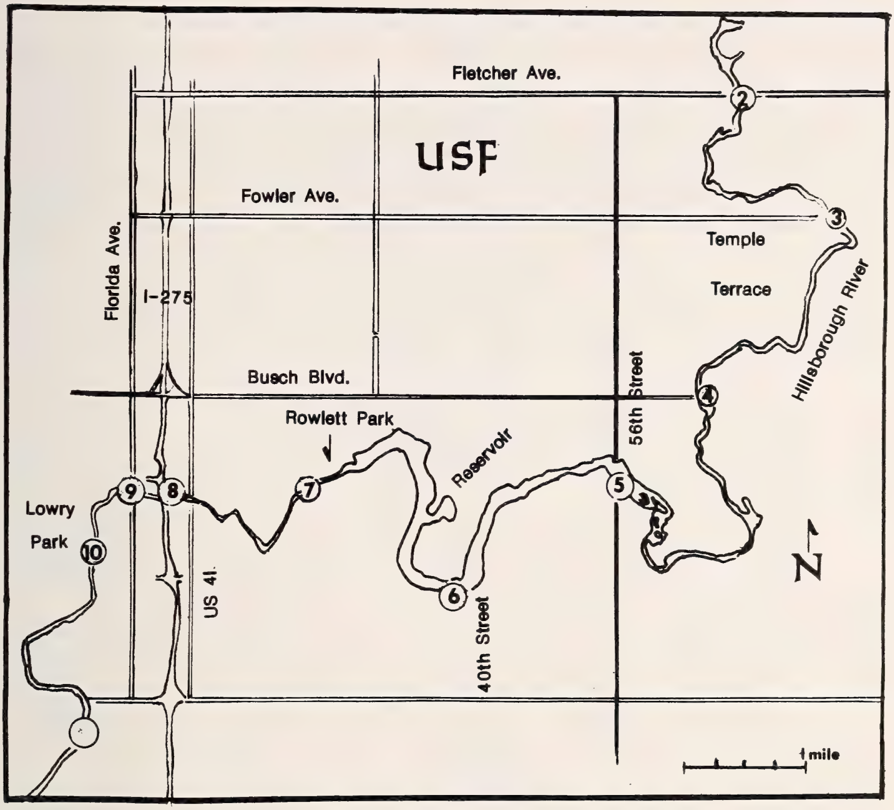

FIG. 1. Source of sediment samples from Hillsborough River.

METHODS—A measured damp sample (5 mL) of sediment and 3.5 mL of 109 ppm Cutrine-plus were placed in a 250 mL stoppered Erlenmeyer flask covered with aluminum foil and made up to 100 mL with KNO_3 solution, 70 ppb NO_3^-N. These samples were placed in a New Brunswick Scientific Model G76 gyrotory water bath at 25°C and shaken continuously for 10 days. Then, 5-mL samples were withdrawn periodically from the mixtures, centrifuged, and analyzed. To inhibit bacterial activity, the centrifuged samples were kept in covered vials at 0 - 4°C prior to analysis and during analysis, in an ice-water bath.

The analytical method determined nitrate, nitrite and N-nitroso concentrations after their conversion to NO by selective reduction. The released NO was then detected using a Bendix Model 8101 chemiluminescence NO_x analyzer (Braman and Hendrix, 1989; Braman and Katz, 1991). The arrangement of the analysis apparatus is shown (Fig.2). Nitrite in solution was reduced at 75 - 80°C to nitric oxide in acidic vanadium(IV) medium. Nitrite and nitrate were simultaneously reduced to NO in acidic vanadium(III) at the same temperature range. Nitrite and N-nitroso were simultaneously reduced to NO in acidic (phosphoric acid) iodide using ethylene glycol as solvent at about 160°C. In all cases, the nitric oxide was removed from the reaction by scrubbing with helium carrier gas flowing into the chemiluminescence analyzer.

Nitrosoamine concentrations were evaluated by difference. Nitrites were separately determined at 75 - 80°C by reduction with vanadium(IV). Nitrates and nitrites were simultaneously reduced at 75 - 80°C by vanadium(III). The nitrate concentration was then determined by subtraction of the nitrite-only concentration from the nitrate + nitrite concentration. In a similar manner, the nitrosoamine concentration could be determined by subtraction of the nitrite-only concentration, obtained with vanadium(IV) reduction, from the total nitrite + nitrosoamine concentration obtained with ethylene glycol/phosphoric acid/iodide solution.

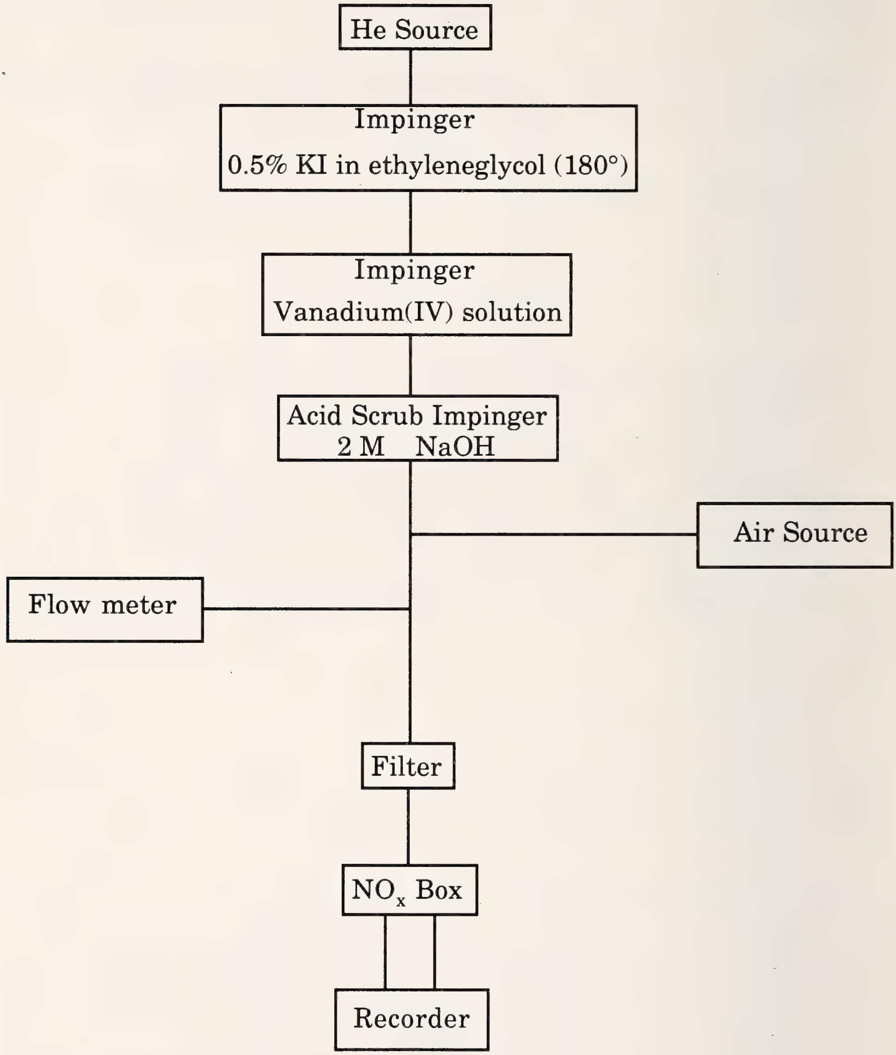

FIG. 2. Schematic representation of the analysis of nitrate, nitrite, and nirosoamine using selective reduction and detection by a chemiluminescence NO_x analyzer.

RESULTS—The results obtained with sediments from four different locations are shown (Table 1). Nitrite determinations by both methods agree within experimental error or within the limitations of the detection method. [Typical calibration plots for NO_2^- as NO and N-nitroso-N-methylaniline as NO were = 0.3319 (ng) + 0.9750 and = 0.2968 (ng) + 1.013, respectively, according to Braman and Katz, 1991]. The sensitivity of the nitrite determination by both methods was similar. The difference between the nitrite analysis in vanadium(IV) solution and the nitrite plus nitrosoamine analysis in hot ethyleneglycol was attributed to the nitrosoamine content of a sample. The concentrations were expressed as ng N. The detection limit of the method was about ± 0.1 ng/sample.

Other mixtures of sediment/water, sediment/nitrate, and sediment/Cutrine-plus were examined using deoxygenated water and normally oxygenated water (Table 2). Mixtures with deoxygenated water (obtained using boiled water) showed a faster build-up of nitrite but much lower nitrite concentrations overall. The lower oxygen content seemed to retard bacterial oxidation of organic nitrogen compounds to form inorganic nitrate and nitrite.

TABLE 1. Nitrite and nitrate concentrations in sediments shaken with NO_3^- and Cutrine-plus for ten days at 25°C.

	ppb Nitrogen as			
	Nitrite	Nitrite + Nitrosamine	Nitrate	N-nitroso
Reducing solution	V(IV)	E.G.[a]/H_3PO_4/I^-	V(III)	E.G./H_3PO_4/I^-
Sample #				
1				
Busch Blvd.	26.61	26.94	57.92	ND
May '90	±1.27	±2.20	±2.24	
2				
Fletcher Ave.	27.58	25.16	55.87	ND
May '90	±2.56	±0.83	±2.40	
3				
56th St. Bridge	14.63	15.15	12.07	ND
May '90	±2.42	±2.12	±2.28	
4				
Busch Blvd.	51.54	50.54	19.68	ND
Aug. '90	±1.54	±1.54	±3.15	

[a]E.G.=ethylene glycol

DISCUSSION—This study is typical of the blend of three contemporary trends in environmental studies: (1) concern for the environmental impact of a chemical species, (2) availability of increasingly sophisticated and precise analytical methods, and (3) conflicting needs. Let us consider these trends in order.

The concern over the use of chelated-copper herbicide arises from an uncertainty about the fate of the chelating agent, and large quantities of chelated-copper applied to Florida waters (cf. Leslie, 1990). An average of 41,000 pounds of copper as chelated-copper was applied annually 1985-1987 in Florida (Leslie, 1990). Given this value and the formula of the metal-chelate compound, we estimate that an average of 79,000 pounds of chelating agent (assuming stoichiometric amounts) was added annually. Clearly, the use of chelated-copper allows less copper to be used, can lead to a more effective use of resources (time and money), and can result in better control of certain target plant species. Against that advantage is the concern over the fate of 79,000 pounds of chelating agent.

That concern is a reasonable one. The reverse of the chelation step could make the ligand available as a nitrogen source, though the chelating tendency of ethanolamine for copper ion (expressed as a formation constant K) is such (log K = 6.68; Bjerrum et al., 1957) that the concentration of free chelating agent is comparatively low, though much greater than EDTA (ethylenediaminetetraacetic acid, log K = 18.87; Perrin, 1979).

In addition, the study of reactions of coordinated ligands has indicated that the act of coordination can render a ligand less reactive (coordinated ammonia is less basic, coordinated cyanide is less toxic), but it can also make the ligand more reactive (coordinated water is more acidic, for example). While simplistic examples were chosen for the sake of clarity (Martin and Martin, 1964), more complicated ones are available (Busch, 1963).

Typically, we might expect that a secondary amine would be required for conversion to a nitrosoamine, but organisms can effect biomethylation, most notably of mercury, but also arsenic, antimony, and tin (Braman, 1975; Braman et al., 1972, 1974, 1978). To that end, it seemed reasonable to investigate the possibility that bacteria contained in sediments might be acting on chelated-copper. The present study used sediment samples from four different areas of the Hillsborough River where chelated-copper might have been reasonably expected to have been applied.

Second, the study was possible because of the development of an improved, precise, convenient, and rapid method of analysis of nitrosoamines (Braman and Katz, 1991) following a previous study of the application of the general approach to analysis of nitrates and nitrites (Braman and Hendrix, 1989). The method does not require an extraction step, and the total nitrosoamines are measured, as opposed to a gas chromatographic method that could measure only volatile nitrosoamines.

Third, the present study derived from a case of conflicting needs. Members of a state regulatory agency (Bureau of Aquatic Plant Management) are properly concerned with the fate of a substance used in large quantities to control plants in potable waters. Those concerns were expressed in a written summary (Leslie, 1990), as well as in a memorandum (Craft, 1990) that generated considerable interest among affected parties. Gianatasio (1990) noted, for example, that the primary source of potable water for the City of Tampa was the Hillsborough River and that within that river [objectionable] "taste and odor is primarily produced by the blue-green Anabaena." He noted, "Until such time as a viable alternative control program is found, the use of Copper Sulfate or Chelated-Copper is using the best available technology [to control Anabaena]." (Gianatasio, 1990). There is, of course, an alternative view that treatment with copper compounds is considerably cheaper than truly best technology, i.e., retrofitting with an ozone device to control geosmin and other odor-producing chemicals produced by cyanobacteria.

The present study indicated that within the limits of experimental error, no nitrosoamines were detected under controlled, environmentally realistic conditions. The possibility, of course, exists that such agents might be produced at less than detected levels. While possible, the matter does not seem

TABLE 2. Nitrite and nitrate concentrations using deoxygenated and normally oxygenated water with the same sediment over a period of twenty days.

Content of Mixture and Mixture #	Days									
	1		3		6		10		20	
	pp^b Nitrogen as									
	NO_2^-	NO_3^-	NO_2^-	NO_3^-	NO_2^-	NO_3^-	NO_2^-	NO_3^-	NO_2^-	NO_3^-
Deoxygenated										
Sediment/water #5	0.00	29.32	4.39 ±0.73 (9.31)	24.12 ±0.77	9.94 ±0.71	52.43 ±2.14	10.91	39.49	0.00	69.91
Sediment/nitrate #6	2.58	88.35	5.85	91.02	3.61	105.69	0.00	99.41	0.00	82.23
Sediment/Cutrine #7	2.75	26.27	3.35	15.87	6.36 ±0.73	30.99	6.07 ±0.64	7.42	6.35 ±0.88 (6.56)*	10.24 ±0.92
Sediment/nitrite/Cutrine #8	—	—	7.13	92.59	21.79 ±1.22	70.13 ±2.23	19.27 ±1.14 (21.56)	64.43 ±1.46	±0.00	±1.69 ±0.55
Normally oxygentated										
Sediment/water #9	0.00	28.47	0.00	23.65	0.00	24.39	0.00	21.07	129.60 ±2.64 (140.40 ±2.97	50.50 ±2.81
Sediment/nitrate #10	0.00	73.51	0.00	64.59	0.00	71.01	0.00	69.78	256.19 ±3.27 (250.41 ±6.67)	105.37 ±3.95
Sediment/Cutrine #11	2.15	25.12	4.82	18.01	9.59 ±1.70	10.89	8.04 ±0.65	10.75	7.97 ±0.03 (0.46)	11.40 ±1.43
Sediment/Cutrine #12	—	—	6.97 ±0.26	111.91	53.11 ±0.67 (54.61)	66.37 ±1.23	55.63 (54.61)	65.72	54.17 ±0.76 (50.87)	61.54 ±1.19

°Values in ( ) represent nitrite concentration obtained at 160°C in E.G./H_3PO_4/I^- reducing solution.

to be of great concern because the concentrations would be notably low, and less than would normally be found associated with certain meats, another example of conflicting needs. We add nitrites to control bacteria in foods, but we are concerned at the possibility that carcinogenic nitrosoamines might be produced. Probably, nitrosoamines are produced, but the body apparently has developed mechanisms for managing certain levels of nitrosoamines. The research of Ames and co-workers (1990a,b) is supportive of this view.

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LITERATURE CITED

AMES, B. N. AND L. S. GOLD. 1990a. Chemical carcinogenesis: too many rodent carcinogens. Proc. Natl. Acad. Sci. USA 87:7772-7776.

, M. PROFET, AND L. S. GOLD. 1990b. Dietary pesticides (99.99% all natural). Proc. Natl. Acad. Sci. USA 87:7777-7781.

ABIDI, S. L., V. K. DAWSON, AND R. C. HUBLEY, JR. 1986. Potential for nitrosoamine formation in seven fishery chemicals. Prog. Fish-Cult. 48:301-302. through: Chem. Abstr. 106: 190523a.

BJERRUM, J., G. SCHWARZENBACH, AND L. G. SILLÉN. 1957. Stability Constants of Metal-Ion Complexes. Special Publ. 6, The Chemical Society, London.

BRAMAN, R. S. 1975. Arsenic in the environment. Pp. 108-123 WOOLSON, E. A. (ed.), *In:* Arsenical Pesticides, ACS Symp. Ser. 7 American Chemical Society, Washington, D.C.

——— AND S. A. HENDRIX. 1989. Nanomolar nitrite and nitrate speciation in environmental waters by vanadium(III) reduction with chemiluminescence detection. Anal. Chem. 61:2715-2718.

——— AND D. L. JOHNSON. 1974. Selective absorption tubes and emission technique for determination of ambient forms of mercury in air. Environ, Sci. Technol. 8: 996-1003.

———, L. L. JUSTEN, AND C. C. FOREBACK. 1972. A direct volatilization—spectral emission type detection system for nanogram amounts of arsenic and antimony. Anal. Chem. 44: 2195-2199.

——— AND KATZ. 1991. Department of Chemistry, University of South Florida, Tampa, Personal Communication.

——— B. B. MARTIN, AND D. F. MARTIN. 1990. Environmental Fate of Chelated-Copper Herbicides. Rpt. to Department of Environmental Regulation.

——— AND M. A. TOMPKINS. 1978. Atomic emission spectroscopic determination of antimony, germanium, and methylgermanium compounds in the environment. Anal. Chem. 50:1088-1093.

BUSCH, D. H. (ed.) 1963. Reactions of Coordinated Ligands. Adv. Chem. Ser. 37, American Chemical Soc., Washington, D.C.

CRAFT, J. A. 1990. Use of copper for aquatic plant manage. Memorandum, May 9, Division of Resource Management, Florida Dept. Natural Resources.

DRUCKREY, H., R. PREUSSMANN, S. IVANKOVIC, AND D. SCHMAHL. 1967. Organotrope carcinogene. Wirkungen bei 65 verschiedenen N-nitroso-Verbindungen on BD-Ratten. Z. Krebsforsch. 69:103-201.

GIANATASIO, J. M. 1990. City of Tampa position statement on the use of copper sulfate for algae control. Presented June 21 in Tallahassee.

LESLIE, A. J. 1990. Copper concerns. Summary presented at meeting, June 21. Bureau of Aquatic Plant Management, Florida Dept. Natural Resources, Tallahassee.

MARTIN, D. F. AND B. B. MARTIN. 1964. Coordination Chemistry, McGraw-Hill, New York.

MEYERS, T. R. AND J. D. HENDRICKS. 1982. A summary of tissue lesions in aquatic animals induced by controlled exposures to environmental contaminant chemotherapeutic agents, and potential carcinogens. U.S. National Marine Fisheries Service Marine Fisheries Review 44(12):1-17.

PERRIN, D. D. 1979. Stability Constants of Metal-Ion Complexes. Part B. Organic Ligands. Pergamon Press. New York.

Florida Scient. 55(3):184-191. 1992.
Accepted: November 19, 1991.

REVIEW

Mayer, John J. and I. Lehr Brisbin, Jr. *Wild Pigs of the United States, Their History, Comparative Morphology, and Current Status,* University of Georgia Press, Athens, 1991. Pp. 313. Price: $40.00.

THIS book goes to considerable lengths to document the past history and current status of the “exotic” or non-native pigs (*Sus scrofa*) widely introduced and thriving in many parts of the United States. It does not include coverage of the “native” pigs or peccaries which are common in parts of the Desert Southwest.

The authors break the free-living *Sus scrofa* down into three genetic subgroups: 1) Eurasian wild boar, 2) feral domestic hogs, and 3) hybrids of these two types. The objectives of this book were listed as follows: 1) to compile a detailed history of the various wild-living populations of *Sus scrofa*, 2) to document the morphological variation exhibited by the various populations and taxonomic forms of *Sus scrofa*, 3) to determine the identifying morphological characters and taxonomic status of the three genetic sub-types of feral swine, and 4) to determine the current status of wild hog populations in the United States.

An exhaustive survey of the history of feral swine introductions is presented on a state by state basis. The references to early Spanish introductions are interesting and colorful, but unfortunately, often short on definitive data.

The chapter on Comparative Morphology clearly presents the differing physical characteristic of domestic swine, feral hogs, Eurasian wild boars, and the sub-group hybrids. Some of the photos showing physical characteristics of wild swine are a bit dark, but generally illustrate the desired details mentioned in the text.

In general, the book is well written and meets the stated objectives of reviewing and determining the status of wild swine in the United States. There seem to be some discrepancies, however, between the 1988 distribution survey of feral swine (appendix E), and the so-called “current survey” conducted by the authors, which are not clearly reconciled. A total of five appendices are presented in the book which add considerable documentation to the wild swine picture.

The literature citation section for the book is reasonably complete, but should probably have included more regarding feral swine in "urbanizing" situations [see Brown, L. N. 1985, ***Florida Scient.***, 48(2):120-123].

This book contains much worthwhile information and data for the wildlife manager, mammalogist, or ecologist interested in the ecology of feral swine.

—Larry N. Brown, Environmental Studies, Inc.,
Box 14244, Tallahassee, FL 32317.

Books Received

FORRESTER, D. J. 1992. Parasites and Diseases of Wild Mammals in Florida. University Presses of Florida, Gainesville. Pp xx + 460, (18 x 26 cm). Price: 59.95 (cloth).

SABROSKY, C. K., G. F. BENNETT, and T. L. WHITWORTH. 1989. Bird Blow Flies *(Protocalliphora)* in North America (Diptera: Calliphoridae) with Notes on Palearctic Species. Smithsonian Institution Press, Washington, D.C. Pp. 312, (15.1 x 22.8 cm). Price: $16.95 (paper).

U. S. DEPARTMENT OF THE NAVY. 1991. Poisonous Snakes of the World. Dover, New York. Pp. 232, (21.3 x27.8 cm). Price: $14.95 (paper).

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Environmental Chemistry

EFFECT OF INORGANIC COMPONENTS ON THE DETERMINATION OF ELEMENTAL CARBON IN AIR PARTICULATE SAMPLES BY REFLECTANCE.

John T. Butcher and R. Del Delumyea

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Abstract: *The determination of elemental carbon (EC) in air particulate matter using optical methods assumes that EC is the only light-absorbing species; however, the presence of significant amounts of (colored) inorganic species would falsely elevate the measured EC concentration. Based on inlet characteristics of the sampling device and particle size distribution, the inorganic content of air particulate samples collected on filters varies significantly. This paper describes the magnitude of this effect for several sampling devices. The interference was found to be 10% or less, depending on the sampling device used.*

Air particulate matter exhibits a bimodal distribution (Shaw, 1987). The fraction of suspended particulate matter (excluding dust) of a size greater than 2.5 micron aerodynamic median diameter is called the "coarse" component. This fraction consists of particles produced by wind (sea salt, continental dust) or mechanical erosion (e.g. tire wear). Those particles greater than one micron in size that enter the nose are filtered out by the nasopharyngeal system and are either expelled or ingested.

The "fine" fraction of atmospheric particulate matter is smaller in size than 2.5 microns. Particles in this fraction are derived mainly from either combustion sources or gas phase condensation. A significant portion of the fine material is input by man. A sample containing both coarse and fine particulate matter contains the Total amount of Suspended Particulate matter, referred to as TSP. TSP is a regulated priority pollutant because it is a potential health hazard and adversely affects visibility.

Elemental carbon—Elemental carbon (abbreviated, EC) is generated as a result of incomplete combustion. It is found primarily in the fine fraction of an air particulate sample. EC is important because it serves as an adsorption surface for other atmospheric components. Being of an inhalable size, it can deposit these adsorbed chemicals in the lung or, for particles smaller than approximately 0.1 microns, directly into the bloodstream. Also, EC contributes to visibility degradation and, being a black-body absorber, has been implicated in global warming. For these reasons, the EC content of an atmospheric particulate sample is often determined as well as the total suspended particulate concentration (Shah et al., 1986; Delumyea and Butcher, 1991). In urban atmospheres, EC accounts for 3-8% of the TSP.

Several methods have been used to determine EC in air particulate samples, ranging from the exotic (including gamma-ray analysis, proton-elastic scattering, and Raman spectrometry) to the more common, such as combustion, photoacoustics, and reflectance. The last method of determining the amount of EC in a particulate sample involves measuring the intensity of light reflected from the filter containing the sample. Elemental carbon is black; therefore, the darkness of the filter provides a quantitative measure of the amount of EC present. However, since the total darkness of a filter is the sum of all the colored components, the presence of other light absorbing species (including such inorganic species as metal oxides) would falsely elevate EC determinations by an optical method. The purpose of this study was to determine to what extent the presence of soil-derived particles would affect the optical determinations of the EC content of atmospheric particulate matter collected by several different sampling apparatus.

Sampling Devices—Most types of sampling devices used to collect air particulate matter involve filtration. In this study, all samplers used the same type of high-purity quartz micro-fiber filters (Type QMA, Whatman Paper Ltd., Maidstone, England). The simplest sampler ("Total") consisted of a downward-facing open-faced 37-mm diameter filter in a rain shield, connected to a pump drawing air through the filter at 16.7 L/min. The reference method (National Archives and Records Administration, 1987) for determining total suspended particulate matter in the atmosphere and the Environmental Protection Agency's Air Surveillance Network, use the High Volume ("Hi-Vol") sampler (Sierra Instruments, Inc., Carmel Valley, CA). The Hi-Vol inlet consists of a roof-like rain shield. This apparatus incorporates a vacuum pump that draws air through a 20.3 cm x 25.4 cm quartz fiber filter mat at approximately 1.4 m^3/min for 24 hr. The Hi-Vol sampler collects both coarse and fine particles.

For studies of inhalable particulate matter, the virtual impactor ("Dichot") uses aerodynamics to separate the fine particles from the coarse. Air is drawn through an inlet which excludes dust and rain and the air stream is split by drawing the majority through an inlet at right angles to the initial flow. Particles small enough to follow the airstream are collected on a filter; particles too large to make the detour are collected on a second filter. Selection of the air flows and orifice diameters allows control of the cut-point. This allows the primarily naturally-occurring components of air particulate matter (coarse) to be studied separately from the predominantly man-made input (fine). The device used in this study was the Dichotomous Sampler, or "Dichot" (Andersen Samplers, Inc., Atlanta GA), the cut-point of which is set at 2.5 microns. It draws air through the inlet at 16.7 L/min for 24 hours, collecting both coarse and fine fractions on 37-mm dia. filters.

Recently, the emphasis on the type of particulate matter that is being collected has shifted. Environmental monitoring agencies are beginning to use the "PM-10" monitor (Mathai et al., 1988). Overall, the instrument is the same as the Hi-Vol but the inlet port characteristics are designed to exclude particles larger than 10 microns in size. It is therefore a hybrid of the Hi-Vol and the Dichot.

For this study, 20 samples were collected in 1990 with each of the four devices mentioned above (Hi-Vol, PM-10, Dichot, and Total) using the appropriate standard procedure.

MATERIALS AND METHODS—The amount of EC present on the filter (or loading), in micrograms per square centimeter, was determined via reflectance and quantified using EC standards generated in the laboratory (Delumyea et al., 1980; Delumyea and Kalivretenos, 1987; Delumyea and Butcher, 1991). The instrument was a modified Light Scattering Monophotometer (C.N. Wood Mfg. Co., Newton, PA), equipped with a xenon arc lamp source and a photomultiplier/amplifier output. The "white" light of the xenon lamp was used without optical filters or a monochromator.

After initial EC determinations were made, the filters were placed in aluminum dishes and heated in 100°C increments to 600°C using a digitally-controlled (±5°C) muffle furnace. After one hour at each temperature, the samples were removed, cooled, and the EC loading again determined.

RESULTS AND DISCUSSION—Organic compounds volatilize or combust at temperatures below 350°C , whereas EC combusts at temperatures between 350°C and 450°C (Delumyea et al., 1980). Above that temperature, quartz filters containing pure butane-generated soot (inorganic free) are white. In ambient aerosol samples, any absorbance that takes place in a sample that has been heated above 450°C should be due to inorganic species. The residual absorbance, therefore, is a measure of the concentration of inorganic materials present. Because larger particles contain correspondingly greater amounts of inorganic fractions, it was expected that the effect would be correlated with the type of sampling device used.

Five of the Coarse and one of the Total samples contained EC below the detection limit of the reflectance method. The remaining samples were averaged and the averages are shown (Fig. 1) at each temperature. Due to their higher flow rates, PM-10 and Hi-Vol samples contained carbon loadings twice those of the Total and Fine samples.

The increase in apparent EC loading at 200°C and 300°C observed for PM-10, Hi-Vol, Total and Fine samples is due to pyrolysis of organic compounds in the sample. Above 350°C. EC combusts to carbon dioxide and by 500°C, carbon is lost completely. Since Coarse (open triangle) samples contain relatively little organic material, charring was not observable. Figure 2, using the same data and legend, shows the percent of original carbon versus temperature for each sample type.

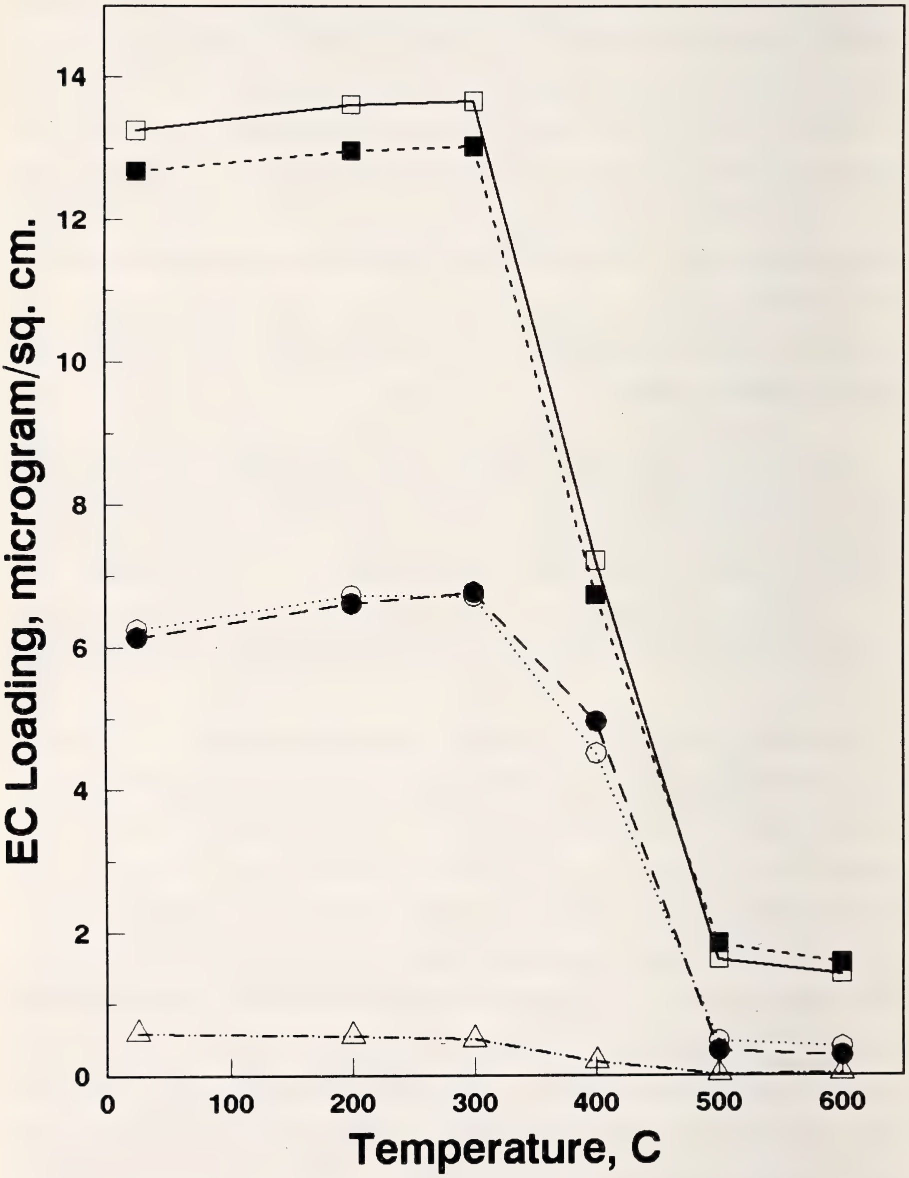

FIG. 1. Elemental carbon loading at increasing temperatures for five sample types: open square, PM-10; solid square, HiVol; open circle, Total; and solid circle, Fine.

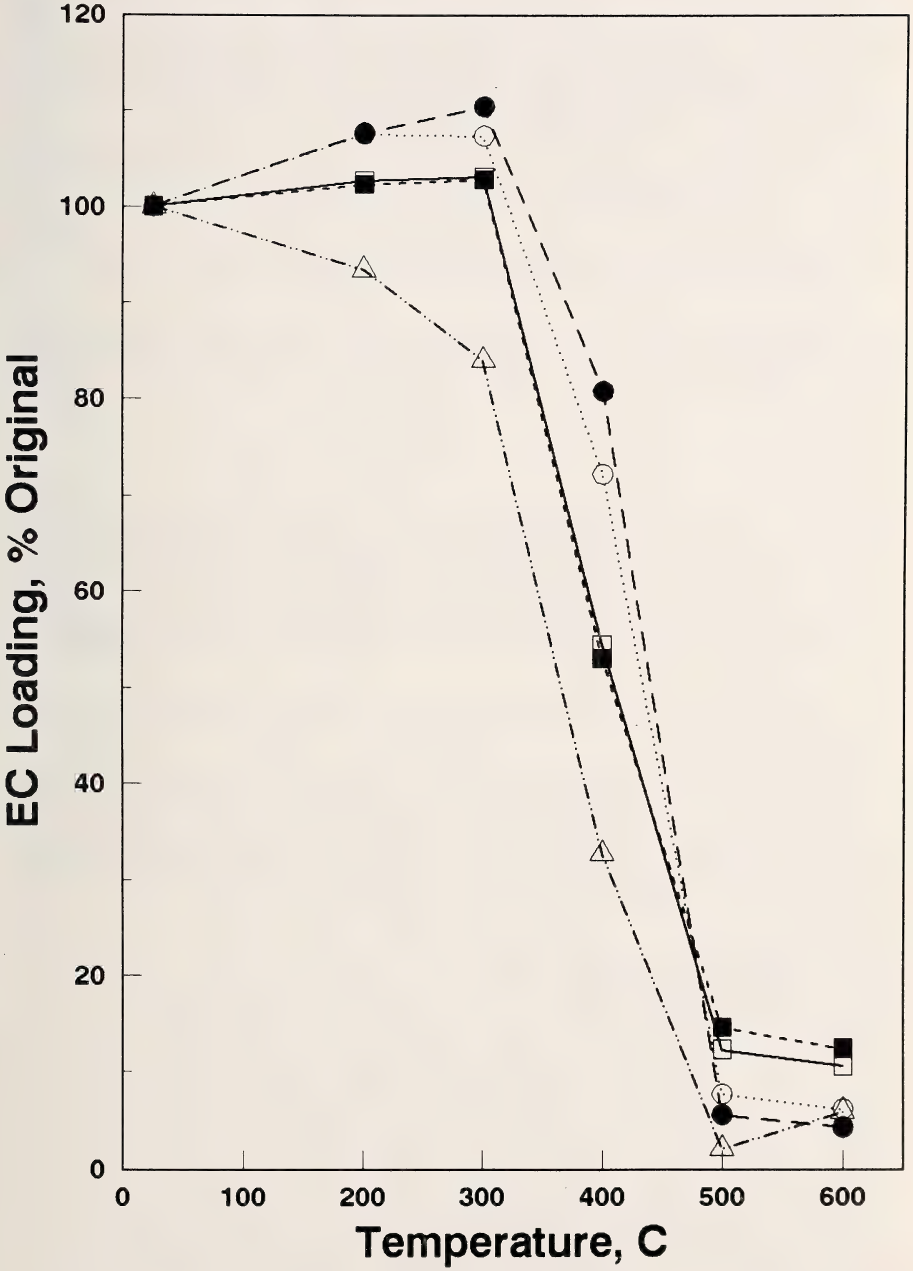

FIG. 2. Change in elemental carbon, expressed as the percent of initial loading, at increasing temperatures for five sample types: open square, PM-10; solid square, HiVol; open circle, Total; and solid circle, Fine.

The amount of residual darkness of each sample after the heating process was about 10% of the original EC loading. Inlet characteristics made little difference in the magnitude of the influence of inorganics on the EC determination. Within the degree of error expected in these determinations (±2%), each of the samples, independent of the sampler, behaved similarly.

Conclusions—Although the conclusion is at present applicable only to the Jacksonville urban aerosols, inorganic materials present in air particulate material, have minimal influence on elemental carbon determinations performed by Reflectance. For filters collected using the sampling devices studied, simple optical methods can be used as a means of EC determination.

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LITERATURE CITED

Delumyea, R. D. and J. T. Butcher. 1991. Impact of toll removal on air particulate concentration in Jacksonville Florida. Air Waste Manage. Assoc. J. 4:1601-1604.

________ , L. C. Chu, and E. S. Macias. 1980. Determination of elemental carbon component of soot in ambient aerosol samples. Atmos. Env. 14:647-652.

________ , and A. Kalivretenos. 1987. Elemental carbon and lead content of fine particles from American and French cities of comparable size and industry, 1985. Atmos. Env. 21:1643-1647.

Mathai, C. V., D. H. Stonefield, and J. G. Watson, Jr. 1988. PM-10 implementation of standsrds. A summary of the APCA/EPA international specialty conference. J. Air Poll. Control Assoc. 38:888-894.

National Archives and Records Administration. 1987. Code of Federal Regulations, Volume 40, Environmental Protection Agency, Part 50, Appendix B, Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High-Volume Method); pp. 558-570; Office of the Federal Register, Washington, D. C.

Shah, J. J., R. L. Johnson, E. K. Heyerdahl, and J. J. Huntzicker. 1986. Carbonaceous aerosols at urban and rural sites in the United States. J. Air Poll. Control Assoc. 36:254-257.

Shaw, R. W. 1987. Air pollution by particles. Scient. Amer. 257:96-103.

Florida Scient. 55(4):193-198. 1992.
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IDENTIFYING A MIXTURE OF CHEMICALS IN A COMMERCIAL PRODUCT FOR MERCURY SPILL ABSORPTION

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ABSTRACT: *A need arose to know with greater certainty the constituents of a commercial product for absorption of liquid mercury spills in view of public inquires for recommendations on such materials and in connection with spill control recommendations being given as part of safety workshops for teachers. We give here our approach to the analysis problem which this material presented and the results of our studies. The usefulness of qualitative chemical tests and the choice of specific spectroscopic techniques such as infrared, x-ray diffraction and x-ray fluorescence for arriving at the identities of at least three components of the mixture as lead metal, zinc metal and sulfamic acid are described. Techniques for quantitative analysis of the identified components in the heterogeneous mixture were developed and gave values of:* $Pb = 82 \pm 3\%$, $Zn = 10 \pm 2\%$ *and* $HOSO_2(NH_2) = 7.1 \pm 0.2\%$. *While it was found that the Material Safety Data Sheet (MSDS) provided by the manufacturer of the product did not include the identities of all constituents, particularly the sulfamic acid which is a strong, corrosive acid, safety precautions they recommended for applying the product seemed adequate. A long-term reactivity of the metal components with the solid acid in the mixture was observed with our samples, but a precise identification of the products could not be made.*

SEVERAL times a year our Departments receive inquiries from the public for information on mercury spill cleanup or mercury-vapor detection means. In most cases the source of the mercury spill in the household is the common mercury-filled fever thermometer which has been broken on the floor, or in handbags, luggage, and such. While we have been successfully utilizing in our own teaching laboratories for a number of years a commercial mercury-absorbing product accompanied by the usual vacuum aspirator technique to clean up mercury spills, we were hesitant to either recommend or supply samples to the public without knowing whether the product itself had any hazards. Furthermore, at that time, as part of the activities of the Safety Committee of the Florida Section of the American Chemical Society we were in the midst of preparing materials for a safety presentation to groups of secondary school science teachers which was to include information on our experience with reported methods and commercially available materials for mercury spill cleanup and mercury-vapor detection, and we desired to have as accurate a knowledge of the materials themselves as possible.

Literature and observations on use of the product clearly indicated that it consisted primarily of small beads of a metal which, when moistened and rubbed on the mercury droplets, formed an amalgam that hardened and could be swept up. Visually however, and more clearly microscopically, it was apparent that a second phase consisting of white, spherically shaped particles was present. Further microscopic observations showed that when this mixture was treated with water, the majority of the white phase dissolved, followed by fairly rapid precipitation of a black, dendritic phase which coated the remaining insoluble, shiny to-somewhat-gray, spherical and tear-drop-shaped metal particles. We were aware that some procedures for amalgamating metals with mercury begin with reduction of a mercury salt to perhaps give a finely divided surface coating (Dodd, 1954). Thus we were concerned that indeed the material might contain a soluble mercury salt and could be hazardous to handle without gloves, although gloves are recommended in the literature accompanying the product. A phone call to company assured us that the product contained no mercury salts but as with most proprietary materials the MSDS supplied with the product at that time (1988) did not reveal specific ingredients other than stating that it contained "granular lead and a proprietary, moderately corrosive organic acid". In the 1990 edition of the the MSDS supplied with the product , the description of the acid was changed from "organic" to "inorganic". Hence, it became of interest to us to conduct qualitative chemical tests and use spectroscopic methods available to us, to obtain more definite information on the chemical make-up of this material. We feel that our approach, the actual means of positive identification and quantitative analysis of the major constituents of the mixture may be of interest to the readership of this Journal. It also seems clear that with the increased emphasis on improvements in the safe handling of chemicals, many of the commonly recommended practices for laboratory spill cleanup will continue to be critically evaluated to ensure their effectiveness and practicability, much as has been done recently in the area of acid-base spills (Nelson, 1986). Our investigation may have relevance to such future efforts in the case of mercury spills.

MATERIALS AND METHODS—Under a low power, binocular microscope the mixture was first physically separated into the major metallic portion and the white solid phase and the identification of these components was attempted separately.

Identification of the white solid phase—For the most part, this phase was water soluble and gave an aqueous solution that was strongly acidic, consistent with the MSDS. Chemically it was felt that it should possess both a reducing agent and a reducible metal salt to account for the apparent formation of the black dendritic precipitate as observed above and which had the appearances of a finely divided metallic phase. The material was mixed and ground with KBr (2 mg/200 mg) and pressed into a disk. Its IR spectrum, taken on a PE 457 grating spectrometer, is shown in Fig. 1. The strong band centered at 3130 cm^{-1} with a shoulder at 3500 cm^{-1} indicated the likely presence of N-H and O-H bonds, respectively, in the solid. Also strong bands centered around the 1300 cm^{-1} region indicated the probable presence of some type of oxo-anion, perhaps containing S-O or N-O bonds (Nakamoto, 1978; Conley, 1972). Thus our initial thought was that it might be an ammonium salt of some type of sulfate derivative. To account for its observed acidity, it was thought that the hydrogen sulfate anion, HSO_4^-, might be a likely candidate but IR spectral comparison did not show good agreement. Similarly, in view of the possibility of the material being a reducing agent, common reducing species such as sulfite, SO_3^{2-}, metabisulfite, $S_2O_5^{2-}$, or hydrogensulfite, HSO_3^- were considered but rejected as unable to account for all bands in the observed IR spectrum. Some resemblance of the S-O region to that of the persulfate ion, $S_2O_8^{2-}$, as seen in the ammonium salt, was noticed but clearly no one-to-one spectral match was obtained (Sadtler, 1967a). Furthermore, the strong oxidizing character of persulfate seemed incompatible with the seemingly required reducing character of this phase. However remembering that persulfates had at one time been used as weed killers we examined an IR spectral compendium on pesticides and herbicides on the chance of finding spectra of possibly related compounds (EPA, 1979). This search did locate a weed killer called Anmate (ammonium sulfamate, $NH_4SO_3(NH_2)$ with similar bands to those of the unknown. While we did not have samples of the ammonium salt, it was decided to run the spectrum of sulfamic acid itself, $HOSO_2NH_2$, which was available to us. The IR of the latter (Fig. 1B) exhibited virtually an identical correspondence to that of the unknown, white solid phase (Fig. 1A). In addition, other chemical properties of the phase were consistent with its identification as sulfamic acid, since the latter is a strong acid with some potential to act as a reducing agent as it is commonly used to reduce nitrites in organic chemistry (Windholz, 1983). Also, previous infrared studies of sulfamic acid have favored the representation of its structure in its zwitterionic form, NH_3^+-SO_3^-. However for the purposes of this paper we retain its representation as an amide derivative of sulfuric acid, $HOSO_2NH_2$ (Vuagnat and Wagner, 1957).

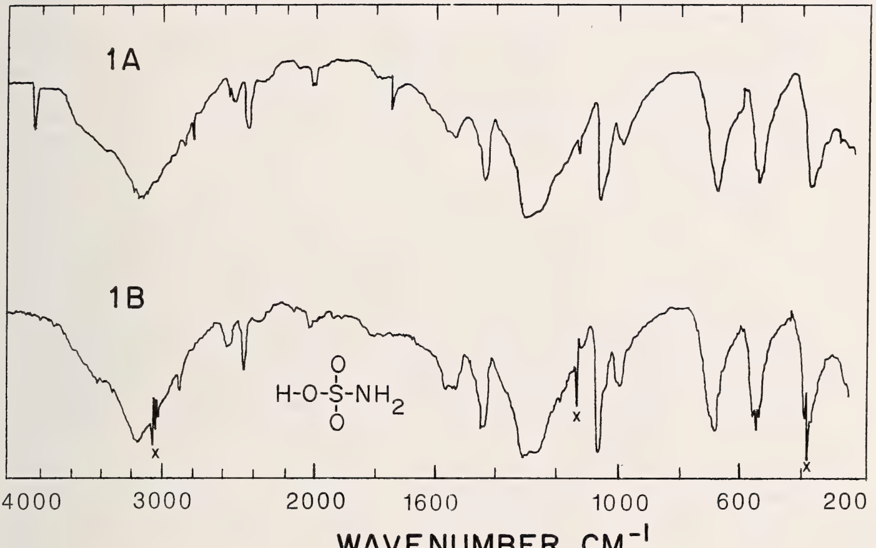

FIG. 1: Infrared Spectra, Perkin Elmer 457 Grating Spectrometer, KBr Disk (2mg/ 200 mg KBr): **A.** Separated, white solid phase portion of commercial-mercury-absorbing powder (fresh); **B.** Reagent grade Sulfamic Acid, $HOSO_2(NH_2)$. Peaks marked with x̲ are instrumental aberrations.

Identification of the metallic phase—After physically separating the majority of the white solid phase, the grayish, metallic-looking principal phase remaining was placed in 1 M HCl. The solution bubbled slightly, but the bulk of the metal remained undissolved even after several days. The supernatant was separated and saved, and more HCl and a few drops of concentrated nitric acid, HNO_3 were added to the unreacted metal phase in a test tube. Upon warming in a Bunsen flame, the metal dissolved readily, and upon cooling, a white solid began crystallizing from the solution. This behavior is characteristic of lead metal, Pb, i.e., relatively unreactive toward dilute HCl, but readily dissolving in the oxidizing acid, HNO_3, with warming (Nechamkin, 1968). When the metal is dissolved in a mixture of the two, the moderately insoluble (at room temperature) lead chloride, $PbCl_2$, precipitates upon cooling the solution.

Next, the supernatant from the initial treatment of the metallic phase with 1 M HCl was investigated. It was neutralized with 10% aqueous ammonia until slightly basic, whereupon a white precipitate formed in the solution. This precipitate redissolved upon addition of excess of the ammonia solution. This behavior was consistent with the presence of zinc ions, Zn^{2+}, in the solution, since this metal possesses an insoluble hydroxide, $Zn(OH)_2$, but which can be solubilized in excess ammonia through formation of the ammonia complex ion, $Zn(NH_3)_4^{2+}$. Thus we conclude that the original metallic phase contained in addition to the lead, some zinc metal, which, being more reactive toward the HCl than lead metal, dissolves in the hydrochloric acid with associated displacement of hydrogen gas. This accounts for the observed bubbling upon original treatment of the metal phase with acid.

X-Ray diffraction measurements—To confirm the composition of the metallic phase as primarily zinc and lead metals as deduced from the above qualitative chemical tests, we chose the x-ray diffraction (XRD) technique, since each crystalline solid has a unique diffraction pattern and an extensive collection of reference patterns exists (JCPDS, 1976a). However, the similarity of crystal structure and unit cell dimensions among the metallic elements can lead to overlapping lines in a diffraction pattern of a mixture. Also the possibility of the metals being present as an alloy could prevent a unique identification of the metal phase by diffraction, and a technique such as x-ray fluorescence, sensitive to elemental composition rather than unit cell parameters, would have to be resorted to. Fortunately neither of these situations occur with this sample as will be shown below.

The sample was prepared for the diffraction measurement by spreading a thin coat of DUCO cement on one side of a glass slide and touching the slide to a sample of the bulk material so as to give a thin film of the materials approximately 2 cm square on the slide. No effort was made to reduce the particle size by pre-grinding since the sample was primarily malleable metal particles. A Philips Electronic X-Ray Powder Diffractometer equipped with a PW1050 vertical goniometer, diffracted beam monchromator (copper $K_{\alpha 1}$ = 1.5404 Å), and theta-compensating slit was used to obtain the diffraction pattern over the 2θ range of 10.00 - 62.50°. Eleven lines were observed in this range, and the 2θ 's at the peak maximas were converted to interplanar spacings, **d**, via the Bragg equation: $\mathbf{d} = \lambda / 2 \sin \theta$ The lines and their observed intensities are listed (Table 1). By comparison with d-spacings of reference patterns for zinc and lead metals, seven out of the eleven observed lines in the pattern of the material could be assigned to these two metals (JCPDS, 1976a,b). Fortunately, since lead has a cubic close-packed structure with face-centered cubic unit cell of edge length a = 4.9506 Å, while zinc is a hexagonally close packed metal with cell dimensions a = b = 2.665 Å, c = 4.974 Å, a = b = 90 °, g = 120 °, there is very little overlapping of their lines in the diffraction pattern except for the coincidences of their lines at 2.486 Å. Four lines in the pattern could not be attributed to the metals and did not agree with the expected lines for sulfamic acid (JCPDS, 1976c), the component identified by infrared spectrometry. However, as we show below, there is a slow, long term reactivity of the components of this material, especially if exposed to humid air. Since the x-ray measurements on the sample were done several months after the original chemical and IR investigations, it is possible that all of the sulfamic acid phase may have been consumed by that time and replaced by the products of that reaction.

X-Ray fluorescence measurements—As a further confirmation of our chemical tests and XRD measurements, the x-ray fluoresence technique (XRF) was also applied. In contrast to XRD, which utilizes the monchromatized, characteristic, K_α x-rays from the x-ray tube for diffraction purposes, XRF utilizes the full range of white radiation emitted, as well, to ionize atoms of the sample. The fluorescent x-rays subsequently emitted by the ionized atoms of the sample are then wavelength-analyzed by allowing them to fall on a face of a single crystal of known d-spacing. From the observed 2θ angles at which they are diffracted from that plane, their wavelengths, which are characteristic of the emitting element, can be deduced using Bragg's Law again in the form: $\lambda = 2 d \sin \theta$. If the K, or n=1 inner shell, electrons are ionized in the sample, K-series x-rays (α, β, etc.) will be emitted as electrons of higher principal quantum number fall into the hole created in the n=1 shell. If the ionization occurs in the L, or n=2 shell, the L-series x-rays will be emitted corresponding to electron transitions from levels with principal quantum number, n>2, into the hole in the L shell.

The sample was prepared for XRF measurement by sprinkling it on the surface of a boric-acid-filled planchet and pelletizing the mixture in a hydraulic press. The sample was then placed in a Philips Electronics XRF spectrometer and exposed to the exciting x-rays from a chromium tube operated at 50 KV. The analyzing crystal was lithium fluoride, LiF, oriented to receive fluorescent x-rays emitted from the sample on its (200) planes of spacing 2.013Å. The 2θ angles at which diffraction was observed are listed in Table 2. After conversion to wavelength and and comparison to literature values of characteristic x-ray wavelengths of the elements (Weast, 1970), the assignments listed in the Table were made. After eliminating two lines arising from some scattering of the exciting chromium radiation, the other five observed lines all show close agreement as belonging to either the K-series of zinc or the L-series of lead metal. Thus the XRF results completely confirm the conclusion from the XRD and chemical tests that the main metals present are lead and zinc. It is interesting though that only the less intense, longer wavelength L-series of x-rays from the lead metal component are observed. This absence of the K-series lines of lead however is consistent with the fact that the short-wavelength-limit of the chromium exciting radiation is only 50.0 Kev, while the K-shell ionization potential of Pb is 87.95 Kev (Weast, 1970).

TABLE 1: Comparison of observed d-spacings and relative intensites of lines in the x-ray diffra tion powder pattern of a sample of the commercial mercury absorbing powder with the reference patterns for lead and zinc metals.

d_{obs}(Å)	I(OBs.)		dPb[a]	I(Pb, Ref)	dZn[b]	I(Zn,Ref)
4.766	24	c	—	—	—	—
3.129	19	c	—	—	—	—
2.873	45		2.855	100	—	—
2.761	26	c	—	—	—	—
2.486	73		2.475	50	2.473	53
2.319	34		—	—	2.308	40
2.102	100		—	—	2.091	100
1.757	26		1.750	31	—	—
1.694	28		—	—	1.687	28
1.586	20	c	—	—	—	—
1.498	20		1.493	2	—	—

a) JCPDS (1976a); b) JCPDS (1976b); c) Unassigned lines, see discussion in text.

Quantitative analysis of components—Once the main constituents of the mercury absorbing material were identified, we conducted some quantitative analyses on the three phases in order to have a firmer basis for any safety judgments of the material as urged by the Editor of the Journal and at the request of a referee in order to establish that the components identified qualitatively really constituted, percentage-wise, the major components of the mixture.

TABLE 2: Comparison of observed x-ray fluorescence[a] wavelengths from a sample of a commercial mercury absorbing powder with accepted values for emission lines for lead and zinc metals.

2 θ (Deg.)	λ(Å)	Int. (Rel.)	Assignment	λ(Å), Lit.[b]
68.85	2.276	58	Cr (Kα)	2.294, 2.290
62.40	2.086	10	Cr (Kβ)	2.085
41.85	1.437	100	Zn (Kα)	1.439, 1.435
37.54	1.295	33	Zn (Kβ)	1.295, 1.293
34.00	1.177	14.5	Pb (Lα)	1.187, 1.175
28.30	0.985	13.5	Pb (Lβ)	0.9828
24.15	0.843	2.2	Pb (Lγ)	0.8396

a) Exciting radiation: chromium, 50 Kv, 35 ma; Analyzer crystal: LiF, (200) plane, d=2.013 Å b) Weast (1970)

Sulfamic acid content, $HOSO_2(NH_2)$—Initial attempts to analyze for the sulfamic acid content of the mixture by titration with standard base yielded variable results in the range of 3.8 → 5.6% by mass. This variability was due primarily to the simultaneous reaction of the zinc component of the mixture with the sulfamic acid component to release hydrogen gas, once the material was wetted, as observed above. The evolution continued until the pH was raised as the titration progressed. To circumvent this problem, we first attempted to rapidly neutralize the acid in the sample with excess base followed by titration with standard acid. However, this approach also failed as the zinc metal component also released hydrogen from the basic solution. The analysis was finally completed satisfactorily by a combination of measurement of hydrogen gas release from the mixture followed by titration of the residual acid following completion of the gas evolution. In a typical analysis a 0.5-g sample was accurately weighed into a 125 mL erlenmeyer flask. A small test tube containing about 6 ml of water was carefully stood upright against the inside wall of the flask. The flask was then stoppered with a 1-hole rubber stopper containing a glass tube to which was attached some small diameter tygon tubing. The other end of the tubing was inserted beneath the water into the end of an inverted, water-filled gas collection buret, positioned upright in a beaker of water. The stopper was pushed tightly into the flask to make a seal and an initial reading of the buret and the water temperature was made. (The barometric pressure was assumed to be close to 1 atmosphere.) The flask was then carefully tilted to spill the water from the test tube to commence the following reaction in the mixture (Eqn. 1).

$$Zn_{(s)} + 2\ HOSO_2(NH_2)_{(aq)} \rightarrow H_{2\ (g)} + Zn\ [SO_3(NH_2)]_{2\ (aq)} \qquad (1)$$

The flask was swirled and reaction allowed to continue until cessation of gas evolution at which point a final gas-buret reading was taken. (Typically, the volume of gas collected was about 2 mL.) Preliminary qualitative tests had shown earlier that the solution above the metallic phase is still acidic at this point even though gas evolution had ceased. Thus the analysis for the remaining acid was completed by careful titration with standard (0.175 M) base to a phenolphthalein end point, which required typically only a few mL of the base. (The final, titrated solution, upon standing, becomes cloudy as zinc hydroxide, $Zn(OH)_2$, or a hydroxy-carbonate precipitates.)

Total moles of sulfamic acid, a monoprotic acid, was determined as the sum of the moles of base from the titration plus one-half of the moles of hydrogen gas collected (in view of the 2:1 stoichiometry, Eqn. 1). For three samples titrated in this way the average mass percentage of sulfamic acid, $HOSO_2(NH_2)$, (MW 97.095), and the standard deviation was 7.1 ± 0.2.%.

Lead and zinc content of the mixture—The fact observed earlier, namely that zinc metal readily displaces hydrogen from solutions of strong acids while lead does not, allowed us to determine these two metals in the presence of each other by relating the amount of H_2 gas displaced to the zinc content of the mixture and obtaining the mass of lead by difference after drying and weighing the unreacted lead metal component after the acid treatment. In a typical analysis a 0.5-g sample of the original, unseparated sample was weighed into the flask of the gas collection apparatus but in this analysis the water in the test tube was replaced with 6 ml of 3 M HCl. The hydrogen gas released was collected in the gas buret after initiation of the reaction by tipping over the test tube. A stable gas-buret meniscus was achieved usually within about 10 minutes. Typical H_2 volumes collected were between 18 - 24 ml. These were converted to moles of hydrogen and, through the 1:1 reaction stoichiometry (Eqn. 1), to moles of zinc. Results for two analyses for Zn gave 10 ± 2% by mass. The undissolved, black residue of lead metal from these two samples was filtered off, dried and weighed to give Pb mass percentages of 82 ± 3%. We attribute the greater variability of the determination of these metals, compared to the sulfamic acid content, as probably due to the physical means by which the two metals are combined in the mixture. It appeared to us that while separate particles of the two metals can be seen microscopically in the sample, a large portion of the metallic phase appears to be composed of lead particles partially coated by the zinc phase. Thus there appears to be considerable heterogeneity in the distribution of the the two metals in the sample.

RESULTS AND DISCUSSION—*Substances found to be present*—Using microscopic examination, qualitative chemical tests, infrared spectroscopy, and x-ray diffraction and fluorescence, we identified three components of a commercial substance for mercury spill clean up as zinc metal, lead metal, and sulfamic acid. Quantitative analysis showed these three substances to be present in the following proportions by mass: Zn = 10 ± 2% ; Pb = 82 ± 3%; $HOSO_2(NH_2)$ = 7.1 ± 0.2%. The closeness of the sum of these percentages, 99.1 ± 3.6%, to 100% assures that these are surely the major constituents of the product within the experimental uncertainty of our results.

With regard to any potential toxicity to a user if contacted by any of these components, we would only consider the sulfamic acid component as possessing a potential hazard in this regard. Information on past studies of the toxicity of sulfamic acid is contained in the Registry of Toxic Effects of Chemical Substances (NIOSH, 1981-82). There, the level of skin irritation it produces in animals is ranked as only “mild” for a 4% solution, to “severe” for the solid acid itself in 24 hour contact with skin. Its oral toxicity value cited there is LDLo = 1600 mg/kg. According to Gosselin and co-workers (1976), sulfamic acid is accorded a toxicity rating of MODERATE, primarily based on its being a strong acid with its solutions being capable of producing corrosive effects to all mucous membranes. Thus, notwithstanding the fact that salts of sulfamic acid are apparently toxic to plants, the simple precaution recommended by the manufacturer in the literature accompanying the product, of wearing gloves when applying the product, along with the additional usually recommended safety practice of wearing goggles whenever acids or alkalis are handled to avoid eye injury if splashed, would seem adequate protection against the corrosive properties of sulfamic acid as a strong acid in the usual context of application of the product. The hydrogen release observed here, when the product is activated by water for use, is also noted in the company's MSDS under physical and chemical properties of the product, though without explanation of its origin.

The use of zinc dust as an absorbant for mercury spills has been noted previously in the safety literature (Anderson et. al., 1978). Presumably, in the commercial product which we studied, the zinc metal component along with, probably, the lead metal component participate in an amalgamation process with the liquid mercury which gives a solidified, easily-collected product in the application of the material for mercury spill clean up. In addition, the role of sulfamic acid as a cleaning agent for removing oxides from the surfaces of metals (Kirk-Othmer, 1969) may be the reason this acid is also utilized in the product, since its surface-cleaning property would presumably aid the amalgamation of the three metals involved.

Observed long term reactivity of the components of the mixture and explanation of the black, dendritic phase—In the course of this study (extending over several years) our original samples of the commercial product, kept only in plastic, snap-cap vials, exhibited a complete loss of their original, strongly acidic reaction when wetted and an increase in the amount of a white phase encrusting the metallic particles appeared. Similarly, even the bulk supply of the material stored in our stockroom in a similar press-in-place-lidded, plastic container exhibited caking and decrease in acidity when tested with moist litmus. Thus it appears likely that the sulfamic acid can interact directly with the metals, probably promoted by slow entry of atmospheric moisture into an imperfectly sealed storage container. The IR spectrum of a sample of this aged material is shown (Fig. 2A). In agreement with the loss of acidity, the broad N-H stretching band of the sulfamic acid near 3130 cm^{-1},originally present (Fig. 1B), has been replaced by a series of sharper bands to higher energy, and most of the other bands have shifted or changed shape except for the doublet at 1000-1070 cm^{-1}.

The most reasonable reaction between the constituents of the mixture to explain these observations would be the displacement of hydrogen from the strongly acidic, sulfamic acid by the reactive zinc metal component to form

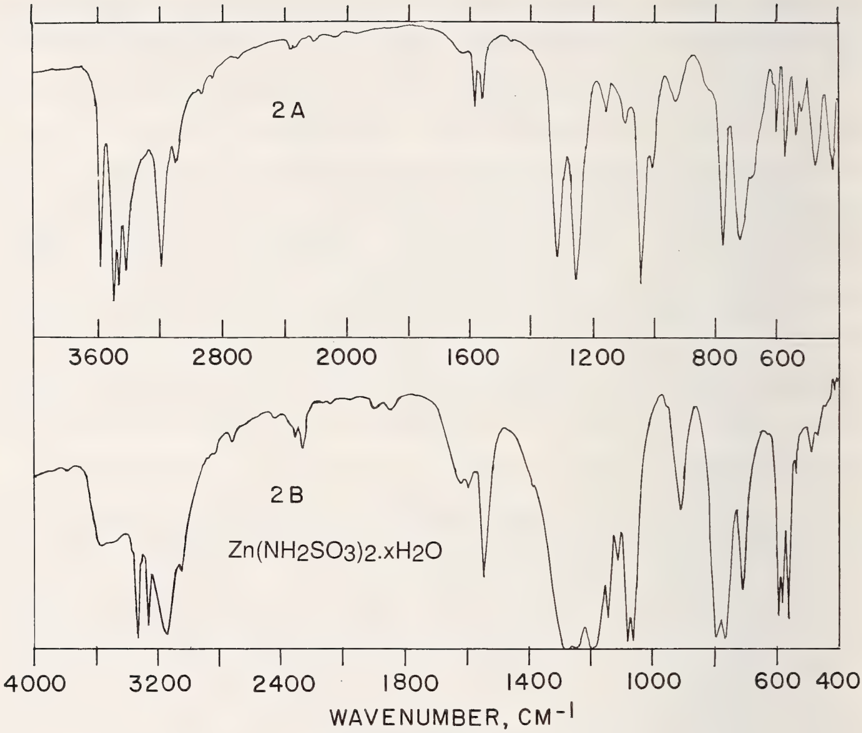

FIG. 2: Infrared Spectra, Beckman FTIR, KBr Disk (2mg/200 mg KBr): **A.** Bulk, aged sample of commercial mercury absorbing powder; **B.** Synthesized sample of zinc sulfamate, $Zn(NH_2SO_3)_2.xH_2O$

sulfamate salts such as $Zn(NH_2SO_3)_2$. However it appears that the reaction may not be that simple. We prepared what we believe to be the zinc sulfamate salt, $Zn(NH_2SO_3)_2.xH_2O$ by neutralization of $ZnCO_3$ with sulfamic acid in a 1:2 ratio, followed by filtration and evaporation to dryness. The material obtained is a hygroscopic glass and the IR spectrum is shown (Fig. 2 B). Though this IR spectrum matches in general aspects those of other metal sulfamate salts, (Bicelli, 1956, 1957; Nyquist et. al., 1979; Sadtler, 1967b), it does not show a one-to-one correspondence with IR spectra of the aged samples of the commercial mercury absorbing powder (Fig. 2A). The latter shows a number of sharp bands in the 3400-3600 region possibly suggestive of metal-coordinated-hydroxide-ion stretching bands, M-O-H, or unusual N-H stretching bands, along with other bands possibly characteristic of the sulfamate anion, $(NH_2SO_3^-)$. Thus the product may be a basic metal salt of this anion.

Finally, we believe there is a relationship between the observed slow reactivity of the components of the material and our original observation of the formation of a black dendritic phase upon activation of the material with water treatment. We speculate that this phase is finely divided lead metal, seen only in samples that have begun to age. Upon the addition of water to the solid before application, the water dissolves the sulfamic acid and the acid subsequently cleans the surface of the metal particles by dissolving any coating of oxides or sulfamate salts that may have occurred during storage. However, any lead ions, $Pb^{2+}(aq)$, that enter the solution from these sources would be immediately reduced to lead metal by the active zinc metal present. Tests performed on very fresh material indicate that only a slight amount of this black, dendritic phase forms, compared to the reaction in aged samples. Thus, we presume that in the aging process, particularly if moisture has entered the container, some of the lead metal can react with the sulfamic acid and be converted to lead salts. However once water is applied to activate the material for mercury spill clean up, any soluble lead salts are subsequently reduced back to finely divided lead metal ("the black dendritic phase") through the reducing power of the zinc metal component of the mixture.

ACKNOWLEDGMENTS—We wish to thank Jane Stevens of the USF/New College Chemistry Department in Sarasota for allowing generous use of their infrared spectrometer and Richard Strom, formerly of the Geology Department at the Tampa Campus of USF, for running the x-ray powder diffraction pattern and the x-ray fluorescence spectrum of the material studied. The assistance of the Florida Toxic Substances Center in obtaining literature citations on sulfamic acid is also acknowledged.

LITERATURE CITED

ANDERSON, D. H., R. O. MURPHY, AND W. W. WHITE. 1978. A cleanup procedure for handling mercury spills. J. Chem. Educ., 55: A72.

BICELLI, L. 1957. Pb, Cd and Ag sulfamate infrared spectra. Anali. di Chimce. 46: 661-670.

, L. 1957. Zn, Cu, Co and Ni sulfamate Infrared Spectra. Instituto Lombardi (Rend. Sc.) 1957, 91: 76-86.

CONLEY, R. T. 1972. Infrared Spectroscopy, ed. 2., Allyn & Bacon, Inc., Boston, Fig. 5.57, p. 208-209.

DODD, R. E. AND P. L. ROBINSON. 1954. Experimental Inorganic Chemistry. Elsevier Pub. Co., Amsterdam p. 167.

GOSSELIN, R. E., H. C. HODGE, R. P. SMITH, AND M. N. GLEASON. 1976. Clinical Toxicology of Commercial Products,. ed. 4., Williams and Wilkins Co., Baltimore, Vol. II, p. 71.

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1979. Manual of Chemical Methods for Pesticides and Devices. Assoc. of Official Analytical Chemists, Arlington, VA 22209.

KIRK-OTHMER, 1969. Encyclopedia of Chemical Technology. (2nd Revised. Edition), A. STANDEN(Exec. Ed). Sulfamic Acid and Sulfamates. John Wiley & Sons, Vol. 19, p. 242-249.

NAKAMOTO, K. 1978. Infrared and Raman Spectra of Inorganic and Coordination Compounds, ed. 3., John Wiley & Sons, New York, p. 437

NECHAMKIN, H. 1968. The Chemistry of the Elements. McGraw-Hill, New York, Pp. 100-104

NYQUIST, R. P. AND R. O. KAGEL. 1970. Infrared Spectra of Inorganic Compounds. Academic Press, New York, Spectrum No. 412

NELSON, N. S. 1986. The AC approach to liquid spill cleanup. J. Chem. Educ. 63: A167-169.

JOINT COMMITTEE ON POWDER DIFFRACTION STANDARDS (JCPDS). 1976a. Powder Diffraction Data: Data Book..ed. 1., Joint Committee on Powder Diffraction Standards, 1601 Park Lane, Swarthmore, PA 19801. Set. 4, Card 686, Lead Metal, Pb.

________. 1976b. Powder Diffraction Data: Data Book. ed. 1., Joint Committee on Powder Diffraction Standards, 1601 Park Lane, Swarthmore, PA 19801. Set. 4, Card 831, Zinc metal, Zn.

________. 1976c. Powder Diffraction Data: Data Book. ed. 1., Joint Committee on Powder Diffraction Standards, 1601 Park Lane, Swarthmore, PA 19801. Set. 6, Card 483, Sulfamic Acid, NH_3SO_3..

NATIONAL INSTITUTE FOR OCCUPATIONAL HEALTH AND SAFETY (NIOSH). 1981-82. Registry of Toxic Effects of Chemical Substances. ed. 1981-82, Dept. of Health Education and Welfare, Public Health Service, National Institute for Occupational Health and Safety, WO5950000, p. 660.

SADTLER RESEARCH LABORATORIES. 1967a. The Sadtler Standard Infrared Spectra. Inorganics and related compounds. Sadtler Research Laboratories, 3316 Spring Garden St., Philadelphia, PA 19104. Vol. I, Spectrum No. Y16K, $(NH_4)_2S_2O_8$.

________. 1967b. The Sadtler Standard Infrared Spectra. Inorganics and related compounds. Sadtler Research Laboratories, 3316 Spring Garden St., Philadelphia, PA 19104. Vol. II, Spectrum No. Y420 K, $Pb(NH_2SO_3)_2$.

VUAGNAT, A. M. AND E. L. WAGNER. 1957. Vibrational Spectra and Structure of Solid Sulfamic Acid and the Sulfamate Ion. J. Chem. Phys. 26: 77 - 82

WEAST, R. C. (ed.) 1970, Handbook of Chemistry and Physics. 51st ed., CRC Press, Inc., Boca Raton, FL, p. E196-198

WINDHOLZ, M. (ed.) 1983, Merck Index, 10th ed., Merck & Co., Rahway, NJ, Compound No. 8793, Sulfamic Acid.

Florida Sci. 55(4):199-208. 1992.
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FLORIDA ACADEMY OF SCIENCES
1992 ANNUAL MEETING
OUTSTANDING STUDENT PAPER AWARDS

AGRICULTURAL SCIENCES

Diego A. Diz, Agronomy Department, University of Florida, "Seed-Related Characteristics of Pearl Millet x Elephantgrass Amphiploid Hybrids." Graduate Co-award.

Timothy A. Lang, Agronomy Department, University of Florida, "Optimal Plant Spacings for Late Season Tropical Corn Production." Graduate Co-award.

ANTHROPOLOGICAL SCIENCES

Dennis Satterlee, Department of Anthropology, University of Florida, "Characterizing El Nino Disasters and Cultural Change, Ilo, Peru: A Preliminary Report." Graduate Award.

Kenneth Winland, Department of Anthropology, Florida Atlantic University, "Projectile Trauma in the Human Skeleton: Estimating Size and Type." Honorable Mention, Physical Anthropology.

Susan Pappas, Department of Anthropology, University of South Florida, "Public Health and Elder Dominicans." Honorable Mention, Cultural Anthropology.

BIOLOGICAL SCIENCES

Melissa Foster, Department of Zoology, University of Florida, "Effect of Highways on Bobcat Survival and Movement Patterns in Southwest Florida." Graduate Award.

Catherine Graham, Natural Sciences Department, Eckerd College, "Dispersal of the Seeds of the Tropical Rain Forest Tree, *Maesa lanceolata*, by Two Species of Bulbul." Undergraduate Award.

ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCES

Mitchell Katz, Department of Chemistry, University of South Florida, "Trace Nitrosamines in Environmental Samples." Graduate Award.

FLORIDA COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS

Steve A. Johnson, Department of Biology, University of Central Florida, "Reproduction Ecology of the Florida Green Turtle (*Chelonia mydas*): Results of Field Work at Melbourne Beach, Florida, 1991." Graduate Award.

(CONTINUED ON PAGE 228)

THE INTERTIDAL VOLUME OF FLORIDA'S INDIAN RIVER LAGOON

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ABSTRACT: *The intertidal volume of Florida's Indian River lagoon is investigated to quantify the range of values occurring over a one-year period of time, and to determine the nature of this temporal variability. Intertidal volumes are calculated for the lagoon as a whole, and for three sub-basins defined by the lagoon's three inlets. A one-year simulation indicates that 38.7 x 10^6 m^3 of water enters and leaves the lagoon on an average semidiurnal tidal cycle. The effective intertidal volume, representing the net exchange, cannot be determined from the historical data base of salinity. The range of 12.6-71.7 x 10^6 m^3 is due more to diurnal inequalities than to differences between spring and neap tide conditions.The northern part of the lagoon, with 65% of the total surface area, contributes only 9% of the intertidal volume. The southern part of the lagoon has 18% of the surface area, but it contributes 63% of the intertidal volume. Harmonic analysis shows that the M_2 constituent is the principal tidal constituent throughout the lagoon. In the northern segment, semidiurnal constituents are damped less than diurnal constituents, and the form number is about 1.5. Elsewhere, the form number is approximately 0.5.*

THE flooding and ebbing of water into and out of an estuary at tidal periods is an important physical process, because of the direct and indirect effects this exchange has on the ecology of the estuary. The tidal current is a reliable transport mechanism for planktonic plant and animal life, as well as for suspended and bedload sediments, in the sense that it is as predictable as it is rigorously periodic. Equally significant is the effect tidal exchanges have on water quality by transporting pollutants. Thus, the characterization of the magnitude of tidal exchanges is of fundamental importance in many kinds of interdisciplinary studies.

Tidal exchanges can be quantified in either of two ways. One approach involves ebb and flood current measurements across the one or more inlets serving the estuary, or across any transverse cross-section in the interior of the estuary. Given sufficient measurements, the products of the current speeds and the cross-sectional areas they represent yield the volume transport. Repeated measurements through full flood and ebb tide cycles quantify the intertidal volume (sometimes referred to as the "tidal prism"), defined as the volume of water that moves into or out of an estuary during any half tidal cycle. Costa (1990) has used this approach in Florida's Indian River lagoon to estimate a value of 53 x 10^6 m^3. More specifically, intertidal volumes of 11, 27 and 15 x 10^6 m^3 were attributed to Sebastian Inlet, Ft. Pierce Inlet and St. Lucie Inlet, respectively. These values represent 21%, 51% and 28% of the total. Temporal variability associated with these values could not be determined. Nor was it possible to determine the effective intertidal volume, or net exchange, over any given tidal cycle.

An alternate approach requires water-level data from throughout the estuary, or from a specific area of interest. The product of the water level, relative to some datum, and the surface area that it represents gives a volume. Again, repeated measurements will quantify the amount of water entering or leaving the study area over one or more tidal cycles. This technique offers an advantage in the sense that it requires data only at times of low and high water. When working in large estuaries, however, several stations may be needed to account for the nonuniform rise and fall in water level as tidal waves move through the interior as progressive waves. Pritchard (1960) has taken this approach in an investigation of Chincoteague Bay. The bay was divided into 16 segments, because the rise and fall of the tide in the interior lagged that at the two inlets by as much as seven hours.

With either approach, one must exercise caution, because measurements made over short periods of time, such as a single tidal cycle, may not represent conditions at other times during fortnightly or monthly cycles. Similarly, diurnal inequalities may vary significantly over time scales on the order of days to weeks. Ideally, one must have data covering a complete synodic month, and then express tidal exchanges in terms of a range of values reflecting the interaction of diurnal and semidiurnal tidal constituents. Because it is generally easier to obtain long time series of water level than to obtain equally long time series of currents throughout a transverse crosssection, the second method described above tends to be more promising for characterizing tidal exchanges and the associated intertidal volumes.

Estuarine flushing studies involving intertidal volumes have been conducted over the past four decades. Ketchum (1951) introduced an analytical model that quantified flushing as a geometric progression involving tidal mixing and freshwater outflow. Austin (1954) took the same approach to estimate the flushing time of Mobile Bay, and a modification of this technique led to the mixing length theory described by Stommel and Arons (1951) and Stommel and Farmer (1952). Although the trend in recent years is toward the use of computer models to simulate estuarine flushing, box models are still in regular use (Officer, 1976; Robinson, 1983; Miller and McPherson, 1991).

Two difficulties arise when using intertidal volumes to estimate estuarine flushing. The first involves the distinction between the intertidal volume and the effective intertidal volume—the amount of water actually exchanged over a given tidal cycle. Ichiye (1973), for example, has shown that the effective intertidal volumes for Old Tampa Bay and Lower Tampa Bay are 2% and 1% of the calculated intertidal volumes, respectively. A second and equally fundamental difficulty stems from the constraint of working with a single intertidal volume value when the interaction of diurnal and semidiurnal tidal constituents can result in a broad range of values.

This paper presents results of an investigation of the intertidal volume of Florida's Indian River lagoon. The lagoon lies along the Atlantic coast of central Florida (Fig. 1). It is 196 km long and generally 2-4 km wide. Water depths are between 1 and 3 m in most areas. The lagoon is flushed directly through

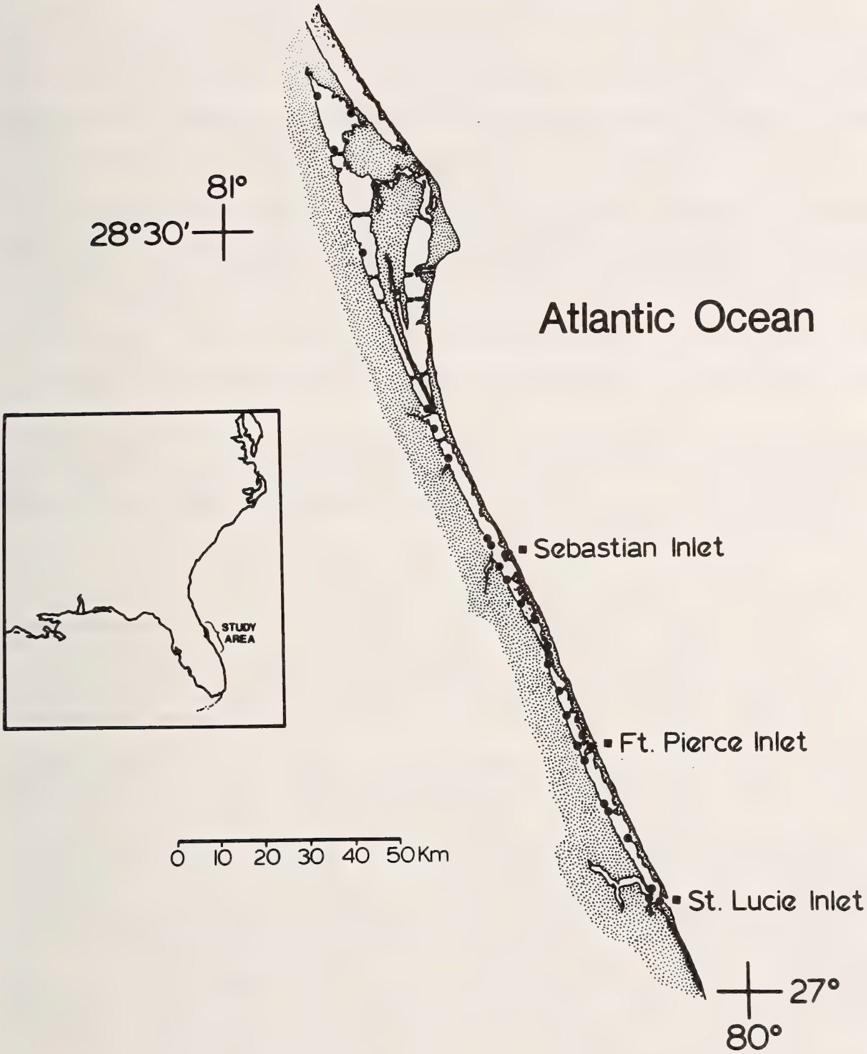

FIG. 1. Indian River lagoon, along the Atlantic coast of South Florida. Solid circles show the locations of the 28 stations used to calculate intertidal volumes. Solid squares show the locations of the pressure recorders off Sebastian Inlet, Ft. Pierce Inlet and St. Lucie Inlet.

three inlets, all of which are found in the southern half. In addition, smaller volumes of water are exchanged with Mosquito Lagoon through Haulover Canal, at the northern end of Indian River lagoon. Tidal conditions have been described for the lagoon as a whole (Smith, 1987, 1990). The M_2 constituent is dominant, but amplitudes are small everywhere in this microtidal lagoon. The M_2 amplitudes are 0-5 cm north of Sebastian Inlet, 5-10 cm between Sebastian Inlet and Ft. Pierce Inlet, and 10-15 cm between Ft. Pierce Inlet and St. Lucie Inlet. High and low tide in the interior of the central and southern segments lag shelf tides by 4.4 and 3.3 hours, respectively (Smith, 1987).

My purpose is to apply Pritchard's approach to quantify the range of intertidal volumes of Indian River lagoon. The data base assembled by Smith (1987) has been expanded by adding six stations, including three in the immediate vicinity of the inlets, where tidal amplitudes are greatest. Also, the analysis used here incorporates six tidal constituents, rather than the five chosen for the earlier study. Results extend Costa's findings (Costa, 1990) by singling out specific subbasins within the lagoon, and by identifying the relative importance of the principal semidiurnal and diurnal tidal constituents. More importantly, the study quantifies temporal variability that arises from spring and neap tide differences and from the diurnal inequality. The resulting range of interdidal volumes, combined with the appropriate exchange ratios, can be used in box models to determine the corresponding range in flushing times.

METHODS—*Data*—Water-level data assembled for this study were obtained using Stevens Model A and Model F analog water-level recorders, and using Stevens Model 7031 digital recorders. Analog records were read to the nearest 0.01 ft or 0.1 cm; the digital recorder provided water levels to the nearest 0.01 ft. Water-level records varied greatly in length, but most were on the order of 2-3 months long.

Surface areas of the 28 segments of the lagoon were obtained using a compensating polar planimeter and NOS navigational charts 11474 and 11476. Each water-level recorder represented a fraction of the total 568 km^2 surface area of the lagoon. As a result of unequal station spacing, individual water-level records represent surface areas of from 1.4 to 87.5 km^2. Partly because of spacing, and partly because tide gauges were positioned along the shore of the lagoon, water-level records may not represent conditions at the midpoint of each segment. Nevertheless, it is felt that the spatial resolution provides an adequate picture of tidal conditions. In general, the poorest spatial resolution is in the part of the lagoon lying north of Sebastian Inlet, where tidal amplitudes and thus intertidal volumes are smallest.

Other Methods—Harmonic analysis (Dennis and Long, 1971) of the water-level records provides the harmonic constants (amplitudes and local phase angles) needed to identify the principal tidal constituents, and to quantify the intertidal volume associated with each. When water-level records were more than about 35 days long, analyses of overlapping time series provided several harmonic constants for each tidal constituents which were then vectoraveraged, as suggested by Haurwitz and Cowley (1975). Only semidiurnal and diurnal tidal constituents were used in this study. Compound tides and overtides arise within the estuary for the most part, and they are of secondary importance within the context of exchanges between the estuary and the adjacent continental shelf. Long-period tides are generally of such low amplitude that they are of minor physical significance. Also, they raise and lower diurnal and semidiurnal high and low tide levels by similar amounts and thus have little effect on intertidal volumes. The importance of nontidal water-level variations on flushing and maintaining water quality is recognized and appreciated (Smith, 1986), but this was outside the intended focus on baseline tidal processes.

Tidal elevations relative to local mean sea level were obtained from vector-averaged harmonic constants using the National Ocean Service tide prediction program (Pore and Cummings, 1967). The water level for the i^{th} constituent in the m^{th} segment, $n_{m,i}$, relative to local mean water level is given as a function of time (Eqn. 1).

$$\eta_{m,i} = A_{m,i} \cos(\omega_i t + \alpha_{m,i}) \tag{1}$$

Here A is the amplitude, ω is the angular frequency, t is time, and α is the modified epoch as defined by Schureman (1958). The water level for the m^{th} segment is obtained by summing the contributions of each of the principal tidal constituents (Eqn. 2).

$$\eta_m = \sum_{i=1}^{6} \eta_{m,i} \cdot \tag{2}$$

The volume of water in the m^{th} segment as a function of time, V_m, is obtained from the product of the predicted water level, η, and the surface area of the segment, S, assuming that the surface area of the segment does not vary as a function of water level. These products were then summed to obtain the hour-by-hour variation of the total volume of the lagoon, V_T (Eqn. 3).

$$V_T = \sum_{m=1}^{28} \eta_m S_m. \tag{3}$$

The intertidal volume, P, is then calculated from adjacent maximum and minimum volumes (Eqn. 4).

$$P = V_{T\max} - V_{T\min} \tag{4}$$

The form number, F, is a convenient measure of the relative importance of diurnal and semidiurnal tidal constituents. Here, F is defined as the ratio of the sum of the amplitudes of the three principal diurnal tidal constituents to the sum of the amplitudes of the three principal semidiurnal constituents (Eqn. 5).

$$F = (K_1 + O_1 + P_1) / (M_2 + S_2 + N_2). \tag{5}$$

By convention, form numbers between 0.5 and 2.0 indicate a mixed tide, while form numbers less than 0.5 or greater than 2.0 indicate increasingly semidiurnal and diurnal tides, respectively.

TABLE 1. Harmonic constants of principal tidal constituents in shelf waters off (A) Sebastian Inlet, (B) Ft. Pierce Inlet and (C) St. Lucie Inlet. Amplitudes, η, are in decibars; local phase angles, ϕ, are in degrees. Form number, F, is defined (Eqn. 5).

			Tidal Constituent					
	F		M_2	S_2	N_2	K_1	O_1	P_1
A. Sebastian Inlet	0.41	η	0.49	0.08	0.12	0.14	0.09	0.05
		ϕ	211	241	193	139	157	139
B. Fort Pierce Inlet	0.37	η	0.46	0.08	0.11	0.12	0.08	0.04
		ϕ	213	247	194	134	156	134
C. St. Lucie Inlet	0.23	η	0.43	0.07	0.10	0.05	0.07	0.02
		ϕ	211	241	188	097	142	097

RESULTS—Table 1 contains the harmonic constants of the principal tidal constituents in inner shelf waters. The rise and fall of coastal sea level force exchanges with Indian River lagoon through the three inlets. Thus, Table 1 provides a logical starting point for an investigation of intertidal volumes that arise as a direct response. In shelf waters, tides are distinctly semi-diurnal. All form numbers are less than 0.5. The M_2 constituent is clearly dominant with an amplitude of just under 0.5 m.

An example is given (Fig. 2) of the temporal variability of the volume of Indian River lagoon in response to the semidiurnal and diurnal ebb and flood of the tide. The one-month time period was selected arbitrarily. The plot reveals a pronounced diurnal inequality, as diurnal constituents are superimposed onto semi-diurnal constituents. The fortnightly transition from spring to neap tide conditions, arising from the interaction of semidiurnal and diurnal constituents, is relatively subtle.

Intertidal volumes were then simulated for January 1 through December 31, 1991. A one-year time period was chosen to include a more representative distribution of intertidal volumes as diurnal and semidiurnal constituents interact. The 705 values occurring during this time period were distributed between 12.6 and 71.7 x 10^6 m^3, with a mean value of 38.7 x 10^6 m^3. For com-

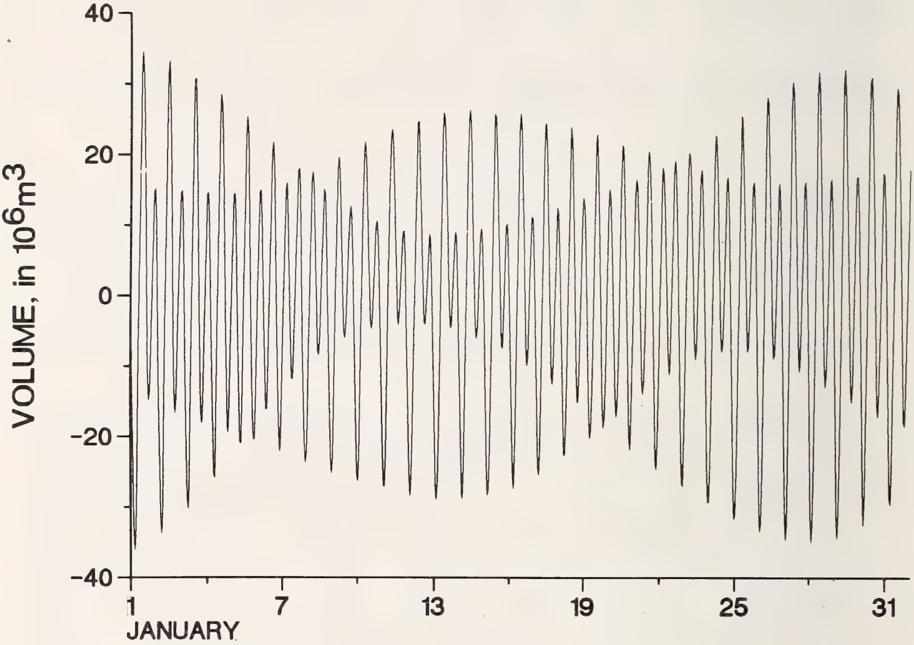

FIG. 2. Volumes of Indian River lagoon, calculated relative to seasonal mean sea level and in response to the three principal semidiurnal and three principal diurnal tidal constituents, January 1991.

parison, the total volume of Indian River lagoon estimated from intracoastal waterway charts is 953 x 10^6 m^3. The mean intertidal volume is 4.1% of this value, and the effective intertidal volume may be substantially less. The median value is very close to the mean, but the histogram of the data (Fig. 3) is flatter than a normal curve and has a kurtosis of 2.13. The histogram shows that in Indian River lagoon a single value for the intertidal volume masks significant temporal variability. It is not clear from the histogram, however, over what time scales the intertidal volume varies through this range. The slightly bimodal distribution is probably a result of the wider range of intertidal volumes arising from the diurnal inequality of the tide.

The 28 individual segment volumes available for each hour can be combined to investigate the intertidal volume in specific sub-basins of the lagoon, as well as for the entire lagoon. Segment volumes from the nine segments north of Sebastian Inlet were used to obtain the intertidal volume for the 113 km long northern sub-basin. The histogram (not shown) had a similar shape and kurtosis; the mean value was 3.6 10^6 m^3, however. Similarly, the mean intertidal volume values for the central and southern sub-basins of the lagoon were found to be 11.1 and 24.3 x 10^6 m^3, respectively. Because of phase differences in the rise and fall of the tide in individual sub-basins, the whole is slightly less than the sum of its parts. It is noteworthy that the northern part of the lagoon constitutes 65% of the total surface area, yet it contributes only

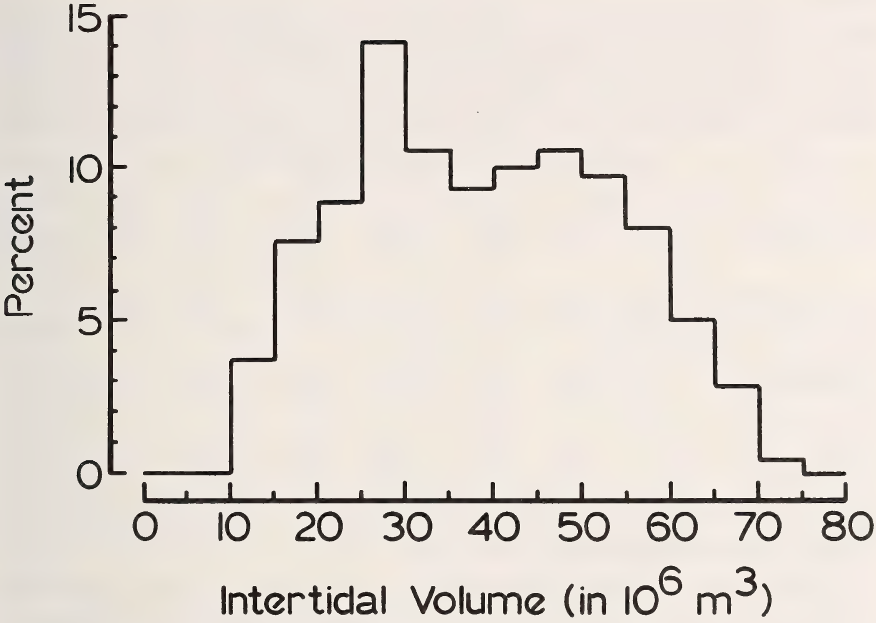

FIG. 3. Histogram of the 705 intertidal volumes calculated for 1991 for Indian River lagoon. Values represent the increase in volume of the lagoon from low tide to the the following high tide level.

9% of the total intertidal volume. In contrast to this, the southern part of the lagoon, with only 18% of the surface area, contributes 63% of the total intertidal volume.

Harmonic analyses of hourly volumes of the three sub-basins of Indian River lagoon, and for the lagoon as a whole, provide information on the magnitude and relative importance of individual tidal constituents. Results are summarized in Table 2. As expected, for the entire lagoon, the M_2 constituent is dominant. The S_2 and N_2 constituents individually can vary the semidiurnal intertidal volume by approximately 10% and 20%, respectively. The combined effect of the K_1 and O_1 constituents indicate a significant diurnal inequality at times of tropic tide conditions.

Results for the northern, central, and southern sub-basins of the lagoon independently reinforce the general spatial pattern obtained from the intertidal volumes noted above: All tidal constituent amplitudes are small in the northern part of the lagoon, but it is noteworthy that the three semidiurnal constituents have been preferentially damped. As a result, the form number is 1.44, indicating a mixed tide. In the central part of the lagoon, intertidal volumes associated with diurnal and semidiurnal constituents are 1-2 and 3-4 times greater, respectively, than in the northern part. This is especially significant in view of the much smaller surface area of the central part of the lagoon. Intertidal volumes increase again by roughly a factor of two from the central to the southern part of the lagoon. In both these areas, the form num-

TABLE 2. Intertidal volumes associated with the six principal tidal constituetns for (A) the entire lagoon, (B) the northern part, north of Sebastian Inlet; (C) the central part, between Sebastian and Ft. Pierce Inlets and (D) the southern part, between Ft. Pierce and St. Lucie Inlets. Amplitudes, n, are in millions of cubic meters; local phase angles, ø, are in degrees. Form number, F, is defined (Eqn. 5).

			Tidal Constituent					
	F		M_2	S_2	N_2	K_1	O_1	P_1
A. Total Lagoon	0.60	η	19.34	2.06	3.55	7.45	4.95	2.47
		ϕ	290	294	281	194	291	194
B. Northern Part	1.44	η	1.65	0.16	0.28	1.60	0.89	0.53
		ϕ	337	221	327	227	279	227
C. Central Part	0.53	η	5.55	0.65	1.11	1.70	1.60	0.56
		ϕ	301	313	282	192	194	192
C. Southern Part	0.55	η	12.19	1.40	2.09	4.17	3.00	1.38
		ϕ	285	299	281	186	190	186

ber is approximately 0.55, indicating a mixed tide only slightly above the accepted cutoff value for semidiurnal tides.

Under certain conditions, the intertidal volume of a portion of an estuary can be used to approximate the associated flood and ebb of the tide into and out of the area in question. In the case of Indian River lagoon, the sub-basin north of Sebastian Inlet can be investigated in this way (ignoring relatively small exchanges through Haulover Canal), because that area is served by only one inlet. Both the central and southern parts of the lagoon are served by two inlets, and it is not clear from the water-level data used in this study how the inlets contribute individually to the total intertidal volume. For the i^{th} tidal constituent, the amplitude of the cross-sectionally averaged tidal current, A', entering or leaving the northern part of the lagoon is obtained by dividing the hourly change in volume by the cross-sectional area (Eqn. 6).

$$A'_i = A_j \, \omega_i / 2 \, S_j. \tag{6}$$

Here A is the amplitude of the tidal period variation of the intertidal volume of the j^{th} sub-basin with surface area S. Smith (1990) has used a cross-sectional area of 3,925 m^2 for the southern end of the northern sub-basin of the lagoon. Using equation (6), the M_2 amplitude is 2.9 cm s^{-1}. This compares with the value of 11.1 cm s^{-1} measured in the Intracoastal Waterway (Smith, 1990), where currents would be expected to be faster than for the cross-section as a whole. Nevertheless, this approach may be useful for calibrating one-dimensional models, such as the one described by Sheng and co-workers (1990).

DISCUSSION—Although the three sub-basins of Indian River lagoon are undoubtedly linked by direct exchanges, results coming out of this study indicate clearly that the northern, central and southern segments of the lagoon have tidal characteristics that distinguish them from one another. The northern segment, for example, is characterized by an unusually small intertidal volume relative to its surface area. To the extent that tidal forcing is responsible for lagoon-shelf exchanges, the northern segment would be the most susceptible to a deterioration in water quality. The southern segment, on the other hand, with only 18% of the surface area, is flushed by 63% of the total intertidal volume. While water quality is defined in terms of water chemistry, as well as the tolerances of resident plant and animal species, in terms of flushing activity, the southern segment would seem to be the most resistant to a lowering of water quality.

The significance of the 12-70 x 10^6 m^3 range in the intertidal volume depends very much upon whether it arises from the difference between neap and spring tide conditions, or whether it is associated with the diurnal inequality of semidiurnal flood tide volumes. If the range varies by a factor of seven over time scales on the order of a week, the period of relatively minor lagoon-shelf exchange might be long enough to permit a significant if temporary reduction in water quality. This does not appear to be the case for Indian River lagoon. Instead, the range is in large part a result of the diurnal inequality (Fig. 2). Thus, minimal flushing may be restricted to periods of several hours, rather than days. Determining the magnitude and the nature of temporal variability of the intertidal volume is as important as determining the exchange ratio and the resulting effective intertidal volume.

A shortcoming of the methodology described here lies in the inability to assign fractions of the total intertidal volume to specific inlets. When an estuary, or a portion of an estuary, is served by two or more inlets, there is no unambiguous relationship between the intertidal volume estimated from water-level records and the relative contributions of the inlets. For information of that kind, one must quantify the intertidal volume by making current measurements in the inlets, or with a lagoon-sized model. Each technique has its advantages, and it may be necessary to employ both to answer all relevant questions.

The significance of the results presented here stems from the magnitude of the intertidal volumes and from the importance of quantifying the range of values, both for the lagoon as a whole and for its individual parts. Although tidal exchanges provide a dependable baseline level of flushing, it is not clear that the intertidal volume, and thus the effective intertidal volume, is sufficient to maintain water quality, especially in the northern part of the lagoon. In a microtidal lagoon such as Florida's Indian River, nontidal processes assume a more prominent role (Smith, 1986). An investigation of flushing rates and residence times must therefore include both tidal and nontidal processes. When the hydrographic data base for Indian River lagoon becomes sufficient to use salinity as a natural tracer, the logical and necessary follow-up to this more highly-focused treatment of intertidal volumes can be undertaken.

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LITERATURE CITED

AUSTIN, G. B. 1954. On the circulation and tidal flushing of Mobile Bay, Alabama, Part 1. Ref. 54-20T, Dept. of Oceanography, Texas A & M Univ., College Station, TX.

COSTA, S. L. 1990. Personal communication. CH2M Hill, Bellevue, Washington.

DENNIS, R. E. AND E. E. LONG. 1971. A user's guide to a computer program for harmonic analysis of data at tidal frequencies. NOAA Tech. Rept. 41, U.S. Dept. Comm., Rockville, MD.

HAURWITZ, B. AND A. COWLEY. 1975. The barometric tides at Zurich and on the summit of Santis. Pure Appl. Geophys. 113:355-364.

ICHIYE, T. 1973. Tides and tidal currents in the eastern Gulf of Mexico. Chapter 8, *In*: ICHIYE, T., H. KUO, AND M. CARNES (eds.). Assessment of Currents and Hydrography of the Eastern Gulf of Mexico. Contr. Nr. 601, Dept. of Oceanogr., Texas A & M Univ., College Station, TX.

KETCHUM, B. H. 1951. The exchanges of fresh and salt waters in tidal estuaries. J. Mar. Res. 10:18-38.

MILLER, R. L. AND B. F. MCPHERSON. 1991. Estimating estuarine flushing and residence times in Charlotte Harbor, Florida, via salt balance in a box model. Limnol. Oceanogr. 36:602-612.

OFFICER, C. B. 1976. Physical Oceanography of Estuaries (and related coastal waters). John Wiley & Sons, New York.

PORE, N. AND R. CUMMINGS. 1967. A fortran program for the calculation of hourly values of astronomical tide and height of high and low water. Tech. Memorandum TDL-6, National Weather Service, Silver Spring, MD.

PRITCHARD, D. W. 1960. Salt balance and exchange rate for Chincoteague Bay. Chesapeake Sci. 1:48-57.

ROBINSON, I. S. 1983. A tidal flushing model of the Fleet—an English tidal lagoon. Estuarine, Coast. Shelf Sci. 16:669-688.

SCHUREMAN, P. 1958. Manual of harmonic analysis and predictions of tides. Spec. Publication No. 98, rev. ed., U.S. Govt. Printing Office, Washington, D.C., 317 pp.

SHENG, Y. P., S. PEENE, AND Y. M. LIU. 1990. Numerical modeling of tidal hydrodynamics and salinity transport in the Indian River lagoon. Fla. Scient. 53:147-168.

SMITH, N. P. 1986. The rise and fall of the estuarine intertidal zone. Estuaries 9:95-101.

——————, N. P. 1987. An introduction to the tides of Florida's Indian River lagoon. I. Water levels. Fla. Scient. 50:49-61.

——————, N. P. 1990. An introduction to the tides of Florida's Indian River lagoon. II. Currents. Fla. Scient. 53:216-225.

STOMMEL, H. AND A. B. ARONS. 1951. A mixing length theory of tidal flushing. Transactions, Americal Geophys. Union 32:419-421.

STOMMEL, H. AND H. G. FARMER. 1952. On the nature of estuarine circulation, Part L, Chapts. 1 and 2. Tech. Rept. Ref. Nr. 52-51, Woods Hole Oceanogr. Inst., Woods Hole, MA.

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OBSERVATIONS ON THE TURTLE COMMUNITY OF RAINBOW RUN, MARION CO., FLORIDA

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ABSTRACT: *The turtle community of Rainbow Run, Marion Co., Florida was studied using mark and recapture methods. Population size and structure were determined for* Sternotherus *minor and* Sternotherus odoratus, *and turtle community structure was compared to results from a study conducted in the 1940s. Profound changes in the turtle community of Rainbow Run have occurred over the last 50 years. Emydid turtles of the genus* Pseudemys *predominated in the turtle fauna in the 1940's, the genus* Sternotherus *predominates today.*

THE clear waters of Florida's spring runs support a diverse vertebrate fauna, of which turtles are a major component. One Florida spring run which has been sampled regularly for turtles is the Rainbow River or Rainbow Run in Marion County (Marchand, 1942; Iverson, 1977). Marchand (1942) reported large populations of *Pseudemys concinna* and *Pseudemys floridana*, moderate numbers of *Sternotherus odoratus*, and small numbers of *Pseudemys nelsoni, Deirochelys reticularia, Chelydra serpentina*, and *Apalone ferox* (Table 1). Recently we resampled the turtle community of Rainbow Run and here describe the size and structure of populations of two species of *Sternotherus* and make comparisons with Marchand's observations on turtle community structure made 50 years ago. This is the first effort to document the changes in community structure of turtles in a Florida river over a prolonged period of time.

METHODS—The turtle community of Rainbow Run, Marion County, Florida, was studied using the mark-release-recapture method as summarized for freshwater turtles by Gibbons (1988). The study was conducted in the 10 hectares of the Rainbow River that form the first 1.46 km (0.91 mi) of spring run immediately north of K.P. Hole County Park, Marion Co., Florida (5.0 km NE Dunnellon). The predominant vegetation and physical features of the run were described by Marchand (1942).

Six species of turtles were collected by 12 snorklers on four dates (5, 9, 16, and 23 January 1990). Samples were collected between 1100 and 1500 in water depths up to 6 m. The majority of turtles were marked and released on the day of capture; fewer than 20% were taken back to the lab, marked, and returned at the beginning of the next sampling period. Turtles returned at a subsequent sampling period were not considered to be marks available for that sample. Marks consisted of deep triangular notches on the peripheral bones. Data taken from each marked turtle included straight carapace length (CL), plastron length (PL), plastron-to-cloaca length, and weight. Sex was recorded if apparent from external appearance of the tail. Plastron-to-cloaca length was plotted against plastron length for all turtles to determine the size at which sexual dimorphism in tail morphology appears (Gibbons, 1988). This method allows determination of sex for smaller adults and some subadults and verifies sex determinations for large adults made in the field. Turtles that failed to show dimorphism in tail length were considered juveniles. Those that were sexually dimorphic in tail length, but had not yet attained the size of sexual maturity for their sex, were considered subadults. Population estimates for two species were made using the

TABLE 1. Composition of the turtle community of Rainbow Run in 1942 and 1990 by species .

	Marchand (1942) %	this study (1990) %
Pseudemys concinna	37.3%	5.0%
Pseudemys floridana	33.3%	3.4%
Pseudemys nelsoni	2.1%	0.2%
Sternotherus odoratus	11.2%	25.0%
Sternotherus minor	n.o.*	66.2%
Apalone ferox	14.2%	0.2%
Deirochelys reticularia	0.7%	n.o.
Chelydra serpentina	0.3%	n.o.

*n.o. = not observed

Lincoln-Peterson index and Schnabel estimate (Ricker, 1975) (Table 2). These estimates are evaluated by criteria offered by Ricker (1975) and Tanner (1978), and are discussed in light of the assumptions of the methods. Weight data and population estimates were combined to calculate the biomass of the two *Sternotherus* species and the turtle community as a whole.

We have not followed the recommendation of Iverson (1991) and chose to use the name *Sternotherus* rather than *Kinosternon*, for the species *minor* and *odoratus*. His study does not fully resolve the relationships among kinosternines and one viable option (Iverson, 1991: Figs. 7 and 8) is that *Sternotherus*, as currently recognized, is a monophyletic group and thus worthy of generic status.

RESULTS—A total of 444 individuals of six species was captured during the four sampling periods, including 294 *Sternotherus minor*, 111 *S. odoratus*, 22 *Pseudemys concinna suwanniensis*, 15 *P. floridana peninsularis*, 1 *P. nelsoni*, and 1 *Apalone ferox*. There was a total of 24 recaptures of *S. minor* and 4 recaptures of *S. odoratus*. These data were sufficient to allow population estimates of 1270 *S. minor* (95% C.I.= 906 - 2121) and 1056 *S. odoratus* (95% C.I.=532 - 52000) for the 10 hectare study area (Table 2), or 127 *S. minor* and 106 *S. odoratus* per hectare. There were no recaptures of any other species.

In addition to providing 95% confidence intervals for our population estimates (Tanner, 1978), we examined the adequacy of our sample size for population estimation using two procedures advocated by Ricker (1975). If the number of marks plus captures is greater than the population estimate then the sample is considered "ideal." If the number of marks times the number of captures is equal to, or greater than, four times the population estimate then "most bias is removed." For both samples, the second inequality is met. The very large 95% confidence interval for *S. odoratus* reflects the small number of turtles handled relative to the large population estimate. However, our five estimates for this population fall between 770 and 1900 (Table 2) and our best Schnabel estimate falls within densities reported for this species in similar habitats elsewhere (see below).

We describe population structure of *Sternotherus minor* in the study area by distinguishing juveniles, subadult females, and adult males and females (Fig 1). We could not determine the sex of individuals 42 mm PL or less, hence 28% of the 228 *S. minor* we measured, were considered juveniles. We were able to determine sex for all turtles larger than 42 mm PL using plastron to cloaca length. Females between 43 and 57 mm plastron length constituted

TABLE 2. Summary of capture, mark, release and population estimates using Lincoln-Peterson (L-P) and Schnabel methods for turtles at Rainbow Run, Marion Co., FL, during January, 1990. One individual each of *Apalone ferox* and *Pseudemys nelsoni* were also captured.

	Captured	Marked and released	Marks available	Recaptures	Lincoln Peterson Index	Schnabel estimate
Sternotherus minor						
5 January	55	30	0	0	—	—
9 January	87	96	30	1	2610	—
16 January	104	79	126	12	1092	1209
23 January	72	0	205	11	1342	1270
Sternotherus odoratus						
5 January	29	29	0	0	—	—
9 January	27	21	29	1	783	—
16 January	38	31	50	1	1900	1342
23 January	19	6	81	2	770	1056
Pseudemys concinna suwanniensis						
5 January	6	6	0	0	—	—
9 January	3	3	6	0	—	—
16 January	6	6	9	0	—	—
23 January	6	6	15	0	—	—
Pseudemys floridana peninsularis						
5 January	0	0	0	0	—	—
9 January	3	3	0	0	—	—
16 January	5	5	3	0	—	—
23 January	6	6	8	0	—	—

6.5% of the population and were considered subadults because turtles of this size are sexually dimorphic but below the size reported for sexual maturity of females of this species (60.1 mm) in central Florida (Etchberger and Ehrhardt, 1987). Females larger than 58 mm PL and males larger than 43 mm PL were considered mature (Etchberger and Ehrhardt, 1987; Etchberger and Stovall, 1990), and constituted 31 and 34% of the total population respectively.

Our sample of 228 measured *Sternotherus minor* included 149 (65.3%) adults, 14 (6.1%) subadults, and 65 (28.5%) juveniles. For the entire sample of *S. minor* for which sex was determined (N=163), the observed sex ratio was 1 female to 0.917 males. This ratio does not differ statistically from 1:1 (X^2=0.30,$P<0.05$). These results are similar to the ratio (1 female to 0.949 males) reported by Tinkle (1958) for a sample of 347 *S. minor* collected from different localities. If subadults (sexually dimorphic turtles below the size of sexual maturity) are deleted from the sample, the sex ratio of reproductive size *S. minor* is 1 female to 1.100 males, again not different from 1:1 (X^2=0.33, $P<0.05$).

The population structure of *Sternotherus odoratus* in Rainbow Run could be described only in terms of adult males and females. This species is sexually dimorphic in tail length at a small size, about 35 mm PL. Males in central Florida mature at about 50 mm CL (±33 mm PL), females mature at about 60 mm CL (±43 mm PL) (Bancroft et al., 1983). The smallest male collected during this study was 51.5 mm CL (36 mm PL); the smallest female collected was 62 mm CL (46 mm PL). Therefore, it was possible to determine the sex of all *S. odoratus* collected. Of 98 *S. odoratus* collected and measured (Fig. 1), 71 were adult males and 27 were adult females.

We calculated the biomass of *Sternotherus minor* to be 12.5 kg/ha using the average mass of the first 100 individuals captured (98.3 gm) and a population estimate of 1270 individuals in the 10 hectare study area. Although the population density of *Sternotherus odoratus* was nearly equal to that of *S. minor*, the average mass of 98 measured individuals was about half (58.1 gm) that of *S. minor* and thus the biomass of *S. odoratus* was half that of its congener (6.1 kg/ha).

We estimated the minimum standing crop biomass for the entire turtle community by adding one-tenth of the mass of all *Pseudemys* and *Apalone* captured in the 10-hectare study area to the per hectare biomass values that were calculated on the basis of population estimates for the two *Sternotherus* species. This minimum estimate is 22.3 kg of turtle per hectare.

DISCUSSION—*Population estimates*—Although six species of turtles were captured, only two, *Sternotherus odoratus* and *Sternotherus minor*, were marked in sufficient quantity to allow population estimates to be made. Use of the Schnabel method (Ricker, 1975) for estimating the population size for these two species in our 10-hectare study area appears to be justified. We have no evidence to suggest that closure or any other of the assumptions under which mark recapture procedures function (Gibbons, 1988; Graham, 1979) have been violated. Given the very short period over which the four samples were taken, there was insufficient time for turtles to lose their marks or for appreciable birth or immigration to occur. Eggs of *S. minor* and *S. odoratus* probably hatch in the late summer (Carr, 1952), so it seems unlikely that new individuals were being added to the population during the sampling interval. The most significant problem is that of closure of the study population, which is an artificial subset of a continuous population. However, examination of more than 52 *S. minor* and 10 *S. odoratus* from the 5 km of spring run downstream from our study area two months after data collection (during March, 1990), revealed no marked individuals and, thus, no evidence of downstream emigration from the study area. The marking system employed was non-debilitating and was unlikely to cause the kind of problems that one might expect from toe clipping lizards or frogs. The two species for which population estimates have been made are bottom walkers (Zug, 1971) that were collected by snorkeling. Thus, there was no opportunity for individuals to become "trap-happy" or "trap-shy", that might have resulted in different catchability of marked and unmarked individuals.

Sternotherus odoratus—The population density of *S. odoratus* in Rainbow Run was calculated as 106 turtles/ha. This figure falls within values given by previous studies of population density for the species (summarized by Iverson, 1982 and Dodd, 1989). It approximates densities reported from an Indiana lake (79.5 /ha), an impoundment in Alabama (148.5 /ha) and a creek

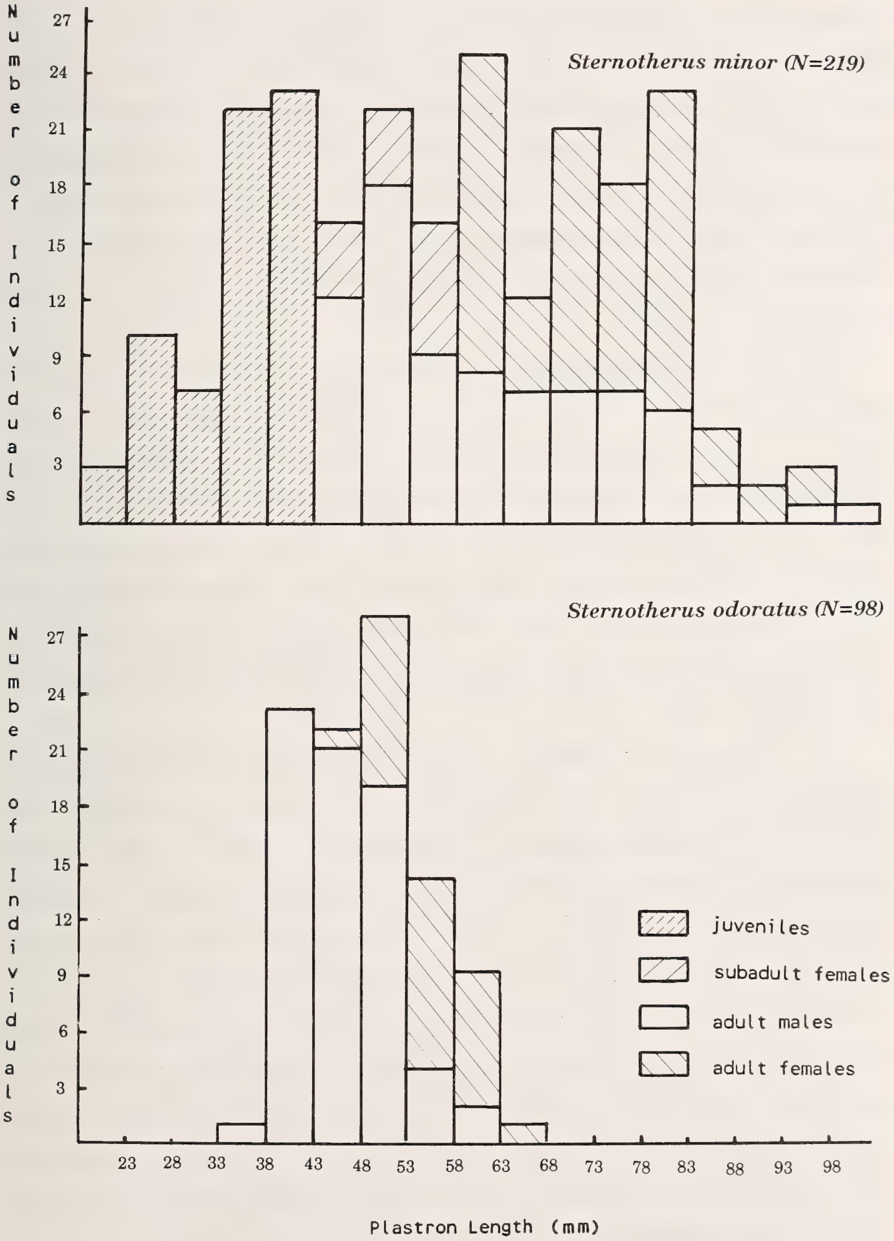

FIG. 1. Population structure for two species of *Sternotherus* from Rainbow Run, Marion Co. Florida, during January, 1990.

in Oklahoma (150 /ha). It is considerably less than the figure of 700 individuals/ha given for a Florida pond but significantly greater than figures available for two temporary ponds in South Carolina, Ellenton Bay and Risher Pond, with densities of 7.8 and 21.9 *S. odoratus*/ha respectively (calculated from Congdon et al., 1986). Density of *S. odoratus* appears to be highly variable and undoubtedly reflects variation in the resources required by this species (Bury, 1979). The density of *S. odoratus* in Rainbow Run seems to be moderate for the species. Density data from all studies combined suggest that *S. odoratus* is more abundant in permanent rather than temporary waters; among permanent bodies, lentic habitats appear to promote greater population density than do lotic habitats.

Estimates of biomass from the literature for *S. odoratus* bracket the estimate from Rainbow Run, 6.1 kg/ha. Studies from Florida, Alabama, Oklahoma and Indiana report biomasses of 41.7, 10.6, 10.2 and 8.4 kg/ha respectively (Iverson, 1982; Dodd, 1989). A study of *S. odoratus* in South Carolina reported a biomass of 1.2 kg/ha for Ellenton Bay and 3.3 kg/ha for Risher Pond (calculated from Congdon et al., 1986). When considered in the light of population densities (see above), the biomasses reported by the Indiana and South Carolina studies seem high. These values are high because of high average turtle mass. These data suggest the possibility that individual *S. odoratus* in areas of lower density may be larger than individuals in areas with denser populations. Alternatively, large size may be an advantage in temporary ponds.

Sexual dimorphism in relative tail length is apparent in *Sternotherus odoratus* from Florida prior to maturity (Bancroft et al, 1983) and was apparent in all *S. odoratus* handled. In our sample the average male *S. odoratus* was 66.0 mm CL, and 91.3% of the males were less than 76.2 mm CL. Nearly all of the females (96.4%) were 71.1 mm CL or larger; the average female measured 76.6 mm CL. These average values for males and females were slightly larger than those reported by Bancroft and co-workers (1983) from Lake Conway, near Orlando, Florida. In that study, the average female was 67.0 mm CL and the average male was 60.0 mm CL. Our five largest females ranged from 81 to 88 mm CL, whereas the five largest males ranged from 77.5 to 81 mm CL. In the Lake Conway population the largest females were 87 to 92 mm CL and the largest males were 79 to 83 mm CL (Bancroft and et al., 1983).

The sex ratio for the *S. odoratus* sample (1 female to 2.5 males) differed significantly ($X^2=18$, $P<0.05$) from the 1:1 sex ratio reported by previous studies (Tinkle, 1958; Bancroft et al., 1983). Dodd (1989) summarized available sex ratio data for this species and suggested that the sex ratio of active *S. odoratus* may vary seasonally, with males being more common in early spring and females more common in summer. If our data are considered to be an early spring sample, they fit this pattern. In addition to the skewed sex ratio, no immature *S. odoratus* were collected. Bancroft and co-workers (1983) reported that juveniles comprised only 1.1% of the *S. odoratus* sampled in Lake Conway, Florida, and suggested that the low relative abundance of immature stinkpots was because very small *S. odoratus* spend their time in dense vegetation in very shallow water. This may explain why juveniles were not represented in our samples. Our March, 1990 sampling downstream of the study area suggests that *S. odoratus* may forage within the flocculent detritus of the river bed. Our collection of this species may have been biased by differential use of this cover by sex and size class in *S. odoratus*.

Sternotherus minor—The population density of *S. minor* in Rainbow Run was calculated as 127 turtles/ha. The only published estimate of population density for *S. minor* reported 2857 turtles/ha from Emerald Springs boil in the Florida panhandle (Cox and Marion, 1979). This population would be twenty times the density of that in Rainbow Run. Spring boils are ideal habitat for *S. minor,* and this may explain the large population size.

The biomass estimate for the Cox and Marion (1979) study was 45.7 kg/ha whereas that for Rainbow Run is 10.2 kg/ha. These values differ by a factor of 4.5 whereas the population density figures differ by a factor of 22.5. The average mass of individual turtles is low for Emerald Springs relative to average mass for Rainbow Run. Thus, the population structure of the Rainbow Run population may be skewed towards adults relative to that of Emerald Springs. Apparently the average mass of individual *S. minor* is larger in areas with small population density as appears to be the case for *S. odoratus*.

The average length of *Sternotherus minor* in Rainbow Run was 71.9 mm CL. Most of the larger turtles were females, but the largest individuals were male (Fig. 1). The five largest males measured 118.5 to 132 mm CL; the five largest females were slightly smaller, 115 to 125 mm CL.

Community structure—In his study of the turtle population in Rainbow Run undertaken approximately 50 years ago, Marchand (1942) estimated that there were about 10,000 turtles in four linear miles of Rainbow Run. This figure would suggest a density of about 2275 turtles in an area the size of our study area, 0.91 linear miles. Our best estimates of the actual density of all turtles in this study during January, 1990, is a similar figure, 2363 turtles. Although the density of turtles in this community appears to have remained stable, examination of the species composition indicates that there has been a significant change in community structure (Table 1).

Marchand (1942) collected very large numbers of *Pseudemys concinna* and *P. floridana*, smaller numbers of *Sternotherus odoratus* and *Pseudemys nelsoni*, and a few individuals of *Apalone ferox, Deirochelys reticularia*, and *Chelydra serpentina*. He did not find *Sternotherus minor* (Marchand, 1942; pers. comm. 1990). In our recent survey *Sternotherus minor* was the most abundant species, followed by *S. odoratus*. Our data suggest that all of the *Pseudemys* species in the area have declined drastically over the intervening years. This genus made up 70% of Marchand's sample and about 7% of our sample.

The three *Pseudemys* species contribute the same relative proportion of the total *Pseudemys* captured in the two studies. *Pseudemys concinna suwanniensis* made up 51.3% of Marchand's *Pseudemys* sample and 58% of ours, *P.*

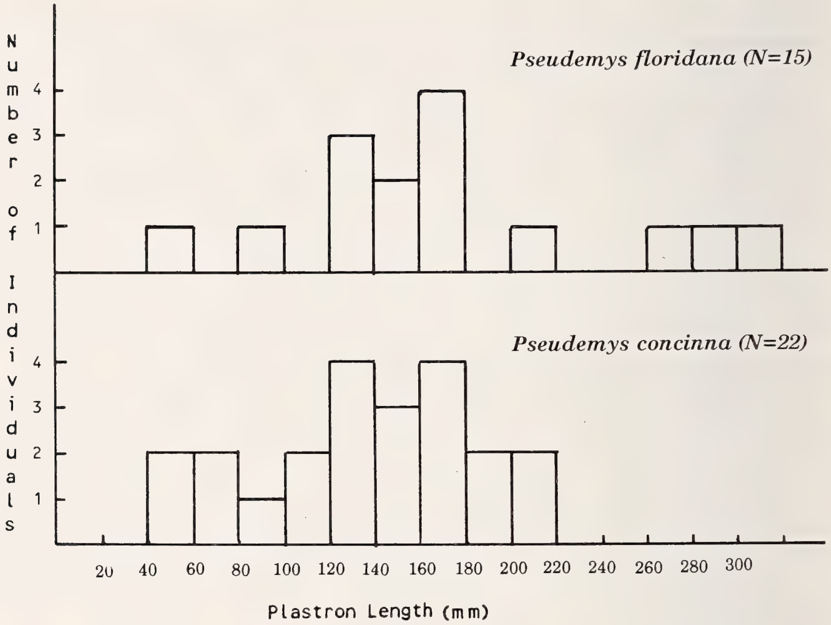

FIG. 2. Population structure for two species of *Pseudemys* from Rainbow Run, Marion Co, Florida, during January, 1990.

floridana penninsularis made up 45.8% and 39% respectively, and *P. nelsoni* made up 2.8 and 2.6% respectively. Thus, the relative abundance of the three species has not changed.

Although there are several possible sources of error in this comparison, none seems sufficient to explain the observed differences in the turtle community structure. Our sample was made by 12 free-swimming snorklers, whereas Marchand's samples were taken by a single snorkler moved along by a boat. In both studies observers were taking turtles freely visible on the bottom or in the water column. Free swimming observers, moving more slowly, might see more small turtles *(Sternotherus)*, but they should not fail to observe larger species *(Pseudemys)*. Observers in our recent sampling effort were asked to keep track of the number of turtles observed but not captured. They were confident that *Pseudemys* species were not escaping more frequently than *Sternotherus*.

It is possible that *Pseudemys* have moved elsewhere on the run or were inactive during this season of the year. However, surveys from K. P. Hole Park to Hwy. 484 suggest that the number of *Pseudemys* is reduced throughout Marchand's study area. Furthermore, Marchand's sampling included winter months. Thus, these explanations do not seem adequate for the 10-fold difference in *Pseudemys* in these two samples. It is more likely that human intervention, through consumption of *Pseudemys* for food (Auffenberg, 1978) or disruption of their normal behavior, has been the major cause of change in turtle community structure. The fact that the three *Pseudemys* species occur in the same relative densities as they did 50 years ago suggests that the factor(s) that have reduced their numbers affect each of them equally. This would be consistent with take for human consumption if the three species were taken as encountered. Furthermore, the majority of *Pseudemys* captured during this study was immature (Fig 2.), suggesting that whatever pressure exists is being exerted on the adults, which would also be consistent with take for human consumption. Alternatively, *Pseudemys* populations may be suffering from an insufficient number of basking sites or high mortality due to boat collisions.

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LITERATURE CITED

AUFFENBERG, W. 1978. Suwannee cooter. Pp. 32-33 *In:* MCDIARMED, R. W. (ed.) Rare and Endangered Biota of Florida, vol. 3, Amphibians and Reptiles. State of Florida Game and Freshwater Fish Comission. Tallahassee, FL.

BANCROFT, G. T., J. S. GODLEY, D. T. GROSS, N. N. ROJAS, D. A. SUTPHEN, AND R. W. MCDIARMID 1983. Large scale operations management test of the use of the white amur for control of problem aquatic plants; The herpetofauna of Lake Conway, Florida: Species Accounts. Miscellaneous Paper A-83-5, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

BURY, R. B. 1979. Population ecology of freshwater turtles. Pp. 571-602 *In:* HARLESS, M., AND H. MORLOCK (eds.) Turtles: Research and Perspectives. Wiley-Interscience, New York, NY.

CARR, A. F. 1952. Handbook of Turtles. Comstock, Ithaca, NY. 542 pp.

CONGDON, J. D., J. L. GREENE, AND J. W. GIBBONS. 1986. Biomass of freshwater turtles: a geographic comparison. Am. Midl. Nat. 115:165-173.

COX, F. B. AND K. MARION. 1979. Population structure and survivorship in the musk turtle, *Sternotherus minor* in a North Florida spring run (Reptilia:Chelonia). Bull. Assoc. Southeastern Biol. 26:84.

DODD, C. K. 1989. Population structure and biomass of *Sternotherus odoratus* (Testudines: Kinosternidae) in a Northern Alabama Lake. Brimleyana 15:47-56.

ETCHBERGER, C. R. AND L. E. EHRHART. 1987. The reproductive biology of the female loggerhead musk turtle, *Sternotherus minor minor*, from the southern part of its range in Central Florida. Herpetologica 43:66-73.

———— AND R. H. STOVALL. 1990. Seasonal variation in the testicular cycle of the loggerhead musk turtle, *Sternotherus minor minor*, from Central Florida. Can. J. Zool. 68:1071-1074.

GIBBONS, J. W. 1988. Turtle population studies. Carolina Tips. 51:45-47.

GRAHAM, T. 1979. Life history techniques. Pp. 73-95. *In:* HARLESS, M., AND H. MORLOCK (eds.) Turtles: Research and Perspectives. Wiley-Interscience, New York, NY.

IVERSON, J. B. 1977. Geographic variation in the musk turtle, *Sternotherus minor*. Copeia 1977(3):502-517.

————. 1982. Biomass in turtle populations: A neglected subject. Oecologia 55:69-76.

————. 1981. Phylogenetic hypotheses for the evolution of modern kinosternine turtles. Herp. Monographs 5:1-27.

MARCHAND, L. J. 1942. A contribution to a knowledge of the natural history of certain freshwater turtles. Master's Thesis. Univ. Florida, Gainesville, FL.

RICKER, W. E., 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Bd. Canada, Bulletin 191.

TANNER, J. T. 1978. Guide to the Study of Animal Populations. Univ. Tennessee Press, Knoxville, TN. 186 pp.

TINKLE, D. W. 1958. The systematics and ecology of the *Sternothaerus carinatus* complex. Tulane Stud. Zool. 6:1-56.

ZUG, G. R. 1971. Buoyancy, locomotion, morphology of the pelvic girdle and hindlimb, and systematics of cryptodiran turtles. Mus. Zool. Univ. Mich. Misc. Publ. No. 142:1-98.

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OUTSTANDING STUDENT PAPER AWARDS (CONTINUED FROM PAGE 208)

GEOLOGICAL AND HYDROLOGICAL SCIENCES

Craig W. Oyen, Department of Geology, University of Florida, "The Significance of Fossil Crinoids from Florida Limestones." Graduate Award.

MEDICAL SCIENCES

Khiro Sanchez, School of Natural and Health Sciences, Barry University, "Ryanodine versus Theophylline-induced Depletion of Energy Contents in Isolated Amphibian Muscle." Undergraduate Award.

PHYSICS AND SPACE SCIENCE

Yin-Fei Chen, Department of Physics, University of Central Florida, "A New Solid State Laser of Ultrahigh Intensity." Graduate Award.

Robert Voor, Department of Physics, University of Central Florida, "Micro-Raman Spectroscopy of Carbon Based Materials." Undergraduate Award.

SPECIAL AWARDS

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AWARD

UNDERGRADUATE AWARDEES:

Catherine Graham, Natural Sciences Department, Eckerd College, "Dispersal of the Seeds of the Tropical Rain Forest Tree, *Maesa lanceolata*, by Two Species of Bulbul."

Robert Voor, Department of Physics, University of Central Florida, "Micro-Raman Spectroscopy of Carbon Based Materials."

HIGH SCHOOL AWARDEES (FLORIDA JUNIOR ACADEMY OF SCIENCE)

Charles Amestro, Tarpon Springs High School, Oldsmar

Eang Ngov, Manatee High School, Bradenton

CENTRAL FLORIDA CHAPTER, THE EXPLORES CLUB AWARD

Louis C. Forline, Department of Anthropology, University of Florida, "Changing Perceptions Towards Indigenous and Rural Peoples: The Convergence of Environmental Issues and Folk/Indigenous Interests."

ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCES AWARD

Elsie Gross, Institute for Environmental Studies, Department of Chemistry, University of South Florida, "Isolation and Characterization of a Hydroxamate Siderophore Produced by *Lyngbya majuscula*."

(CONTINUED ON PAGE 235)

THE EFFECT OF ARTIFICIAL REEF SIZE ON SPECIES RICHNESS AND DIVERSITY IN A FLORIDA ESTUARY

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Abstract: *We experimentally investigated the colonization of artificial reefs by fish and motile invertebrates in the Halifax River lagoon system. The reefs were composed of glued stacks of 60 cm long pieces of PVC pipe. Four reefs of each of three sizes (internal volumes of 1800, 3600 and 6030 cm*^{3}*) were placed in 1 m deep water from February 1990 to January 1991. The organisms in the reefs were sampled in spring (17 April 1990), summer (9 June 1990), fall (10 November 1990), and winter (7 January 1991). The number of colonists, species richness, and species diversity were significantly higher in larger reefs. These parameters, however, did not increase as fast as reef volume. The small reefs had significantly higher species richness per unit volume than the medium and large reefs. Reef size did not significantly affect the density of colonists. Size-independent aspects of artificial reefs, such as shape, are therefore likely to be more important than size in determining ideal reef design.*

Many habitats can be thought of as ecological islands (Begon et al.,1990). An ecological island is an isolated area of one habitat surrounded by a different type of habitat. Artificial reefs are habitat islands as an artificial reef is an area of a hard, three-dimensional habitat often surrounded by soft sediments with little topographic relief. Artificial reefs have been shown to increase the numbers of individuals, species richness and diversity in areas where shelter-seeking species have little or no natural cover (Alevizon and Gorham, 1989; Moring et al., 1989; Bohnsack, 1991).

The purpose of this study was to examine the relationship between reef size and the abundance and diversity of sheltered organisms. We do not attempt to determine if artificial reefs increase the abundance of organisms or species richness of areas that previously lacked such habitat structures. This experiment can be used to help determine the reef design that maximizes the number of sheltered organisms. Specifically, are a few large artificial reefs superior to many small reefs in increasing the number and diversity of sheltered organisms?

Methods—*Study site*—We conducted this study near the seaward edge of Strickland Bay (29°05' N, 81°58' W), a shallow estuary located on the western side of the Halifax River lagoon system (Fig. 1). The margins of the bay were covered by salt marsh dominated by *Juncus roemerianus* and scattered areas of black mangrove *(Avicennia germinans)*. Oyster *(Crassostrea virginica)* bars and mudflats were also common in the lower intertidal zone. This site was chosen for our experiment because it had large expanses of fine sediment with little topographic relief in the subtidal zone. In areas that lack three-dimensional structures, artificial reefs are likely to increase the abundance of species that require structural refuges from predators. This site provided a location where the artificial reefs were easily accessible at low tide. Human-produced debris, the lower edges of the oyster beds, and tree falls provided other subtidal three-dimensional structures.

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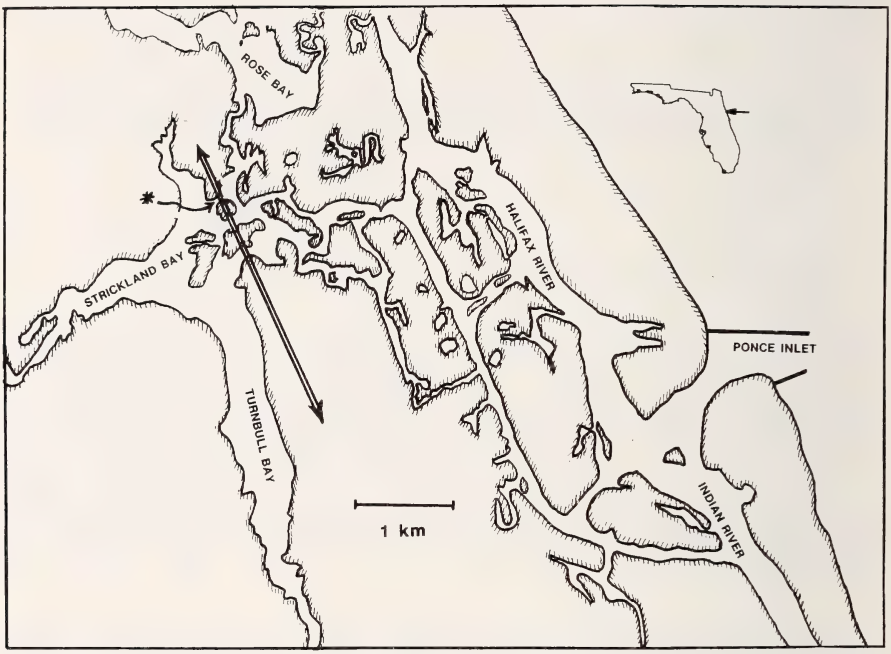

FIG. 1. A map of the study site (indicated by the arrow with an asterisk at its base, the double line indicates the position of highway 1).

Experimental design—Three sizes of artificial reefs composed of PVC pipe (internal diameter = 3.2 cm) were used in this experiment. The pipe was cut into 60 cm lengths which were stacked and glued together. Reefs made with different numbers of stacked pipes served as the different treatments in our experiment. We had reefs composed of three, six or ten pipes with internal volumes of 1800, 3600 and 6030 cm^3, respectively (Fig. 2). With bolts, we anchored each stack of pipe to a concrete block that was approximately 5 cm thick, 20 cm wide and 60 cm long. The ends of all pipes were open. The reefs were placed in a randomized block design which consisted of four blocks (groups of reefs); each block had one replicate of each of the three treatments. The four blocks were placed 5-10 m from a 30 m long oyster bed (two blocks on either side) at a depth of 1 m at low tide. The reefs within a block were placed approximately 1 m apart and the blocks were spaced approximately 20 m apart. The reefs were deployed on 21 February 1990.

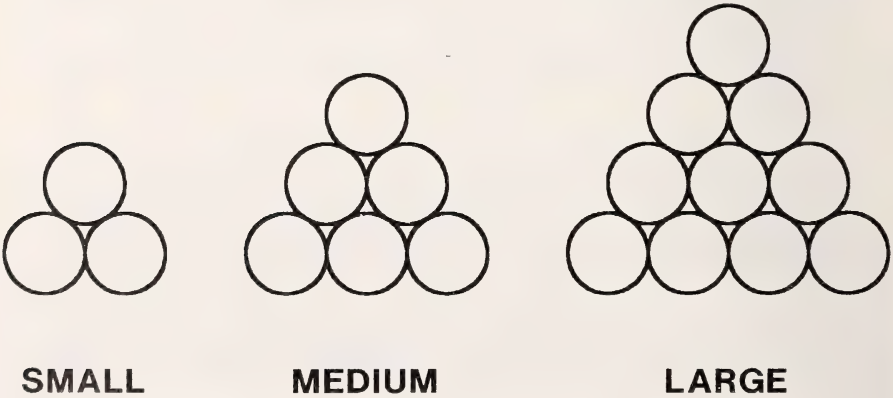

FIG 2. The arrangement of tubes in the small, medium and large reefs (end view).

Data collection—Reefs were initially sampled on 17 May 1990 (spring). In sampling, the ends of the tubes were closed while the unit was underwater. The contents of the tubes were then poured through a 0.3 cm mesh net. The tubes were inspected visually to ensure that all motile macroscopic organisms were collected. These organisms were counted and identified. The defaunated reefs were cleaned and returned to their original positions less than an hour after they were sampled. Subsequent collections were made on 9 July 1990 (summer), 11 October 1990 (fall) and 7 January 1991 (winter).

Data analysis—For each reef we determined the number of macroscopic motile organisms, the number of species present (species richness), and calculated the Shannon-Wiener index (H') of species diversity (Begon et al., 1990). The data were analyzed with two-way ANOVA for a randomized block design using the Systat software system (Systat, Inc. Evanston, IL) at a significance level of $p<0.05$. The two factors in these analyses were sample time and reef size. We used a Tukey-Kramer test (Sokal and Rohlf, 1981) to determine which treatments showed statistically significant ($p<0.05$) differences when an ANOVA indicated an overall statistically significant effect.

RESULTS—The artificial reefs were colonized by a variety of organisms. The dominant sessile species included *Crassostrea virginica* (eastern oyster), *Crepidula plana* (white slipper shell) and several species of acorn barnacle (*Balanus* spp.). The common motile species were a gastropod *(Urosalpinx cinera)*, decapod crustaceans, and fish (Table 1). The dominant crustaceans were shrimp *(Alpheus heterochaelis, Penaeus* sp., *Lysmata wurdemanni)* and a mud crab *(Panopeus herbstii)*. The most abundant fish species was the toadfish *(Opsanus tau)*. The species composition of colonists did not appear to be strongly influenced by reef size or sampling period (Table 1).

Number of organisms—No significant effects of position (the blocking factor), sampling period or the interaction between sampling period and reef size on the number of organisms of all species in the reefs were found (Table 2). There was a statistically significant effect of both reef size and the number

TABLE 1. Species found in the artificial reefs. Listed values are the total number of individuals in all 12 reefs for each season (Sp-spring, Su-summer, F-fall, W-winter) and the total number of individuals in 16 samples from reefs of each size (four replicates in each of four seasons; S-small, M-medium, L-large).

	Season				Reef Size		
Species	Sp	Su	F	W	S	M	L
Class Osteichthyes							
Opsanus tau (oyster toadfish)	8	14	17	11	10	19	21
Mycteroperca microlepis (gag)	1	0	0	0	0	0	1
Lutjanus griseus (gray snapper)	6	0	6	3	1	6	8
Bathygobius soporator (frillfin goby)	7	0	6	3	2	3	3
Gobiosoma bosci (naked goby)	1	8	4	1	3	5	6
Class Gastropod							
Urosalpinx cinerea (oyster drill)	0	18	22	1	4	13	26
Diodora cayenensis (keyhole limpet)	0	0	0	1	0	0	1
Class Polychaeta							
unidentified species	0	0	0	1	1	0	0
Class Malacostraca							
Penaeus sp. (commercial shrimp)	17	2	7	0	1	9	16
Alpheus heterochaelis (snapping shrimp)	16	15	18	21	20	17	33
Lysmata wurdemanni (peppermint shrimp)	0	1	2	0	0	2	1
Callinectes similis (lesser blue crab)	2	9	4	0	3	5	7
Menippe mercenaria (stone crab)	0	0	0	1	0	1	0
Panopeus herbstii (Atlantic mud crab)	23	12	16	17	13	15	38

of organisms that inhabited the reef (Tables 2 and 3). A Tukey-Kramer test indicated that the mean number of organisms in the large reefs was significantly greater than the mean in the small and medium-sized reefs. The difference in mean number of organisms in the medium and small reefs was nearly significant (p=0.059). While the total number of individuals per reef increased in larger reefs, there was no significant effect of reef size on the density of individuals (Tables 2 and 4).

Species richness—No significant effects of position or the interaction between size and sampling period on the total number of species in the reefs were found (Tables 2 and 3). There were significant effects of both reef size and sampling period on species richness. A Tukey-Kramer test indicated that significantly more species were found in the large reefs compared to the medium and small reefs, but that medium and small reefs did not differ significantly from each other. A second Tukey-Kramer test showed that the only significant difference in mean species richness among sampling periods was that the fall sample had higher richness than either the spring or winter samples.

The density of species (species per unit volume) was influenced significantly by reef size (Tables 2 and 4). A Tukey-Kramer test indicated that the small reefs had significantly higher species richness per unit volume than either the medium or large reefs. Season also influenced the density of species. A Tukey-Kramer test indicated that species richness per unit volume was lower in spring than in fall but that none of the other differences between seasons were statistically significant.

Species diversity—No significant effects of position or the interaction between size and sampling period on the species diversity of the reefs were found (Table 3). As with species richness, there were significant main effects of both reef size and sampling period on species diversity (Table 3). A Tukey-Kramer test indicated that the only significant difference in species diversity

TABLE 2. The effects of season and reef size on the number of individual organisms, species richness and species diversity (H') in the artificial reefs (n=12 for season means and n=16 for reef size means, St. Error-standard error of the mean, other abbreviations as in Table 1). For number of individuals and species richness the results are expressed as both mean number per reef and mean number per 1000 cm^2 of volume.

		Season				Reef Size		
		Sp	Su	F	W	S	M	L
A. Individuals								
Per Reef	Mean	6.67	6.41	8.00	6.17	3.69	6.09	10.69
	St. Error	1.40	1.13	1.11	0.87	0.44	0.86	0.71
Density	Mean	1.78	1.69	2.14	1.76	2.05	1.68	1.77
	St. Error	0.31	0.23	0.19	0.21	0.24	0.24	0.12
B. Richness								
Per Reef	Mean	3.25	3.92	5.12	3.25	2.75	4.00	4.94
	St. Error	0.41	0.38	0.53	0.34	0.30	0.36	0.40
Density	Mean	0.94	1.20	1.50	0.97	1.53	1.11	0.82
	St. Error	0.12	0.17	0.17	0.11	0.17	0.10	0.06
C. Diversity								
	Mean	0.89	1.35	1.47	0.99	0.83	1.21	1.48
	St. Error	0.15	0.15	0.14	0.11	0.12	0.13	0.09

TABLE 3. Result of analysis of variance for number of individual organisms (A), species richness (B), and species diversity (C) calculated per reef (block=effect of spatial blocking of reefs, Date=main effect of sample period, size=main effect of size, size*time=sample period by reef size interaction effect).

Source	Sum-of-Squares	DF	Mean Square	F-ratio	P
A. Number of Individuals					
Block	31.90	3	10.62	1.23	0.32
Date	24.06	3	8.02	0.93	0.44
Size	405.50	2	202.75	23.41	>0.01**
Size*Time	26.00	6	4.33	0.50	0.80
Error	285.85	33	8.66		
B. Species Richness					
Block	4.93	3	1.47	1.01	0.40
Time	29.40	3	9.80	6.76	<0.01**
Size	38.54	2	19.27	13.29	<0.01**
Size*Time	10.29	6	1.72	1.18	0.34
Error	47.85	33	1.45		
C. Species Diversity					
Block	0.75	3	0.25	1.28	0.30
Time	2.85	3	0.95	4.82	<0.01**
Size	3.36	2	1.70	8.53	<0.01**
Size*Time	0.44	6	0.07	0.38	0.89
Error	6.50	33	0.20		

TABLE 4. Result of analysis of variance for the density of organisms (A) and species richness (B).

Source	Sum-of-Squares	DF	Mean Square	F-ratio	P
A. Number of Individuals					
Block	4.16	3	1.39	1.85	0.16
Time	1.53	3	0.51	0.68	0.57
Size	1.16	2	0.58	0.77	0.47
Size*Time	2.97	6	0.50	0.66	0.68
Error	24.74	33	0.75		
B. Species Richness					
Block	0.80	3	0.27	1.29	0.40
Time	2.38	3	0.79	3.81	<0.02*
Size	4.06	2	2.03	9.77	<0.01**
Size*Time	0.64	6	0.11	0.52	0.79
Error	6.86	33	0.21		

occurred in the comparison of large reefs with small reefs. A second Tukey-Kramer test showed that the only significant difference in mean species diversity among sampling periods was that the fall sample had higher species diversity than the spring sample.

DISCUSSION—Most previous studies of artificial reefs have focused on reefs in oceanic, not estuarine environments (reviewed by Bohnsack, 1991). The reefs used here provided shelter for only six species of fish. Seven species of decapod crustacean and two motile gastropods were also found in the reefs. The low diversity of fish we observed is not surprising given the limited number of species that inhabit the northern half of the Indian-Halifax River lagoon system relative to the southern half of this system (Snelson, 1983; Brown-Peterson and Eames, 1990). The study site was located near the mouths of Spruce Creek and Turnbull Creek. Variable freshwater input into this system probably causes large salinity fluctuations that further limits species richness.

Our results indicate that species richness increased in the larger reefs. Similarly, we found that the number of motile macroscopic organisms and their diversity increased in the larger reefs. The relationship between these factors and reef size is not a linear function of reef volume. The density of organisms was not influenced by reef size and the density of species declined in the larger reefs. Previous studies had either found no effect (Alevizon et al., 1985) or a decrease (Shulman, 1984; Schroeder, 1987; Bohnsack, 1991) in the density of organisms with increased reef size. Rountree (1989) also found that fish density declined with increased size of his fish aggregation devices.

Seasonal variation occurred in both species diversity and species richness per reef. The increased richness and diversity in the summer and fall was not due to an increased species richness in the total community at that time. The total number of species observed in all the reefs combined stayed relatively stable over the course of this study (spring=9 species observed, summer=8 spp., fall=10 spp., and winter=10 spp.). The higher average diversity and richness per reef in the summer and fall both resulted from a less aggregated distribution of individuals in many species at these times, so that each reef tended to be occupied by more species.

These results indicate the utility of an experimental approach in determining optimal reef design. Further research could investigate the importance of reef size over a larger range of sizes. Since reef size does not strongly influence the density of sheltered organisms, other aspects of reef design, such as the size of holes (Molles, 1978; Hixon and Beets, 1989), are likely to be more important considerations in the design of artificial reefs for this estuarine system.

Acknowledgments—We thank M. Madison and the members of Stetson University's advanced ecology course for help in setting up this experiment. We also thank J. Crowther, and K. deBaets, M. Madison, R. Moore, and B. Scharf for help in collecting samples. D. Martin, Peter May and two anonymous reviewers gave us helpful comments on the manuscript.

LITERATURE CITED

Alevizon, W. S., and J. C. Gorham. 1989. Effects of artificial reef deployment on nearby resident fishes. Bull. Mar. Sci. 44:646-661.

Begon, M., J. L. Harper, and C. R. Townsend. 1990. Ecology: Individuals, Populations and Communities. Blackwell Scientific Publications. Boston, MA.

Bohnsack, J. A. 1991. Habitat structure and the design of artificial reefs. Pp. 412-426. *In:* Bell, S. S., E. D. McCoy, and H. R. Mushinsky (eds.). Habitat Structure: The Physical Arrangement of Objects in Space, Chapman and Hall, NY.

Brown-Peterson, N. and R. W. Eames. 1990. Ichthyofauna associated with spoil islands in Indian River Lagoon, Florida. Florida Scient. 53:226-238.

Hixon M. A. and J. Beets. 1989. Shelter characteristics and Virgin Island fish assemblages: experiments with artificial reefs. Bull. Mar. Sci. 42:666-680.

Molles, M. C. 1978. Fish species diversity on model and natural reef patches: experimental insular biogeography. Ecol. Monogr. 48:289-305.

MORING, J. R., M. T. NEGUS, R. D. MCCULLOUGH, AND S. W. HERKE. 1989. Large concentrations of submerged pulpwood logs as fish attraction structures in a reservoir. Bull. Mar. Sci. 44:609-615.

ROUNREE, R. A. 1989. Association of fishes with fish aggregation devices: effects of structure size on fish abundance. Bull. Mar. Sci. 44:960-972.

SCHROEDER, R. E. 1987. Effects of patch reef size and isolation on coral reef fish recruitment. Bull. Mar. Sci. 41:441-449.

SHULMAN, M. J. 1984. Resource limitation and recruitment patterns in a coral reef fish assemblage. J. Exp. Mar. Biol. Ecol. 74:85-109.

SNELSON, F. F., JR. 1983. Ichthyofauna of the northern part of the Indian River lagoon system, Florida. Florida Sci. 46:187-206.

SOKAL, R. R. AND F. J. ROHLF. 1981. Biometry. W.H. Freeman and Company, New York, NY.

Florida Scient. 55(4):229-235. 1992.
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AWARDS (CONTINUED FROM PAGE 228)

FLORIDA INSTITUTE OF TECHNOLOGY CHAPTER, SIGMA XI AWARD

W. Schlese Heidelbaugh, Department of Oceanography, Ocean Engineering, and Environmental Sciences, Florida Institute of Technology, "An Evaluation of the Methods for Assessing Changes in the Coverage of Seagrass Beds Over Time."

UNIVERSITY OF FLORIDA CHAPTER, SIGMA XI AWARD

Diego Diz, Agronomy Department, University of Florida, "Seed-Related Characteristics of Pearl Millet x Elephantgrass Amphiploid Hybrids."

VICE ADMINAL WILLIAM W. BEHRENS, JR./FLORIDA INSTITUTE OF OCEANOGRAPHY AWARD

No award presented for 1992.

NB: We are grateful to Dr. Carl Luer, Mote Marine Laboratory, Sarasota. As Chairman of the Academy Awards, he coordinated the judging and complied the list of awards.

FOOD HABIT COMPARISON OF TWO POPULATIONS OF BLUE TILAPIA, *OREOCHROMIS AUREUS* (STEINDACHNER), IN NORTH CENTRAL FLORIDA[1,2]

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ABSTRACT: *Food habits of two populations of blue tilapia,* Oreochromis aureus *(Steindachner), in north central Florida were compared for type, amount, and energy of foods consumed. Blue tilapia in Lake Alice consumed mostly diatoms (probably detrital in nature), whereas blue tilapia in Lake George ingested mostly epiphytic green algae and diatoms. Stomach fullness was highest in fall samples and lowest during spawning (March and April) months in both lakes. Total energy values (kilocalories/gram dry weight) were significantly ($\underline{P}$<0.05) higher in Lake George than Lake Alice. The relative digestibility of foods was also higher in Lake George, but assimilable energy values were higher in Lake Alice. Blue tilapia appear to maintain populations in thermally suitable habitats with both epiphytic and epipelic sources of algal foods.*

BLUE tilapia, *Oreochromis aureus* (Steindachner), is presently the most widely distributed exotic fish species in Florida (Zale, 1984). Their interactions with and impacts on native species has been of concern since their introduction into Florida in 1961 (McBay, 1961; Buntz and Manooch, 1968; Courtenay and Robins, 1973; Taylor et al.,1984). Mainly herbivorous, tilapia gain nourishment from sources not often consumed by native species (Bowen, 1984). Although blue tilapia have been shown to ingest mainly phytoplankton, they also are considered very flexible in the types of foods consumed (Spaturu and Zorn, 1976; Foote, 1977; Hendricks and Noble, 1978; Drenner et al., 1984), but little is known of the basic dietary requirements of any tilapian species (Winfree and Stickney, 1981).

Knowledge of the types, amounts, and energy of foods ingested by blue tilapia may contribute to a better understanding of their interactions with native species in Florida waters. The objectives of this study were to compare types, amounts, and energy of the foods eaten by blue tilapia in two north-central Florida lakes with different algal communities.

STUDY AREA—Blue tilapia were collected from two north-central Florida lakes. Lake Alice, (Alachua County), is a 33-ha hypereutrophic lake with approximately 8 ha of open water. Lake George (Lake, Marion, Putnam, and Volusia Counties) is a 18,212-ha meso-eutrophic river-lake formed as part of the St. Johns River.

In Lake Alice, we sampled only the 8 ha of open water due to inaccessibility of the 25-ha waterhyacinth, *Eichhornia crassipes*, marsh. Cattail, *Typha*

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spp. occurred along less than five percent of the open water shoreline. No other aquatic macrophytes occurred within the lake area sampled.

In Lake George, a four-kilometer section along the west shore, from Salt Cove to Silver Glen Springs Run, was sampled. Blue tilapia were also collected from the 0.5-km stream (a thermal refuge) connecting Silver Glen Springs to Lake George in the winter when sampling in the lake failed to collect fish. The dominant (>95% coverage) aquatic macrophyte at the Lake George study site was *Vallisneria americana* (Michaux). Other aquatic macrophyte species noted within the study area included: *Ceratophyllum demersum* (Linneaus), *Potomogeton* spp., *Hydrilla verticillata* (Royle), *Spirodela polyrhiza* (Linneaus), *Salvinia rotundifolia* (Willdenow), *Eichhornia crassipes* (Martius), and *Typha* spp.

METHODS—Blue tilapia were collected for food analysis by electrofishing during fall (October-December, 1985), winter (February - March, 1986), spring (April - May, 1986), and summer (August-September, 1986). Preliminary sampling indicated blue tilapia began feeding in the morning and usually had greater stomach contents by the afternoon. Therefore, we collected fish in the afternoon (1200 to 1600) to obtain samples with freshly eaten food in the stomachs. Tilapia were placed on ice immediately after capture to minimize post-capture digestion. In the laboratory, fish were measured (total length, mm) and weighed. The digestive tract was removed from each fish and contents from the stomach and the hindgut (posterior 15-20 cm of the intestine) were hand stripped into separate 100 mL plastic bottles. The contents of each section were weighed. During the spawning season (March-April), gut contents of brooding females were excluded from food analyses if eggs were found in their stomachs because electrofishing caused some brooding females to swallow their eggs (personal observation).

Three size groups (100-250 mm, 251-350 mm, and >350 mm) were studied. Stomach and hindgut contents of 10 fish in each size group were separately pooled for food analysis. We attempted to collect three pooled samples per size group in each sampling period. All contents were frozen until analyses were performed.

Comparison of food intake was made by using an index of fullness (F) (Eqn. 1). Here S =

$$(F) = 100(S/W) \tag{1}$$

stomach content weight (gms) and W = fish weight (gms) (Spaturu and Zorn, 1978).

Composition of the diet was determined by the presence of different taxa (identification to genus when possible) in one millimeter Sedgwick-Rafter counting cells. Ten milligrams (wet weight) of sample was placed into each counting cell, diluted with distilled water to fill the cell and observed at 200X. Five counting cells were examined for each pooled sample. The percent composition of major food groups (Algae: Chlorophyta, Chrysophyta, Cyanophyta, Euglenophyta; vascular plant material; animal material; and detritus) within each sample was obtained by visually approximating the percent surface area comprised by different food groups in each cell.

Food utility was estimated by subtracting the percent composition of a food group in the stomach from the percent composition of that food group in the hindgut. For algae, the absence of pigment from plant cells indicated an assumption that the cell was digested. Digested cells were not included in the estimation of the percent composition of food groups in the hindgut.

Total energy (kilocalories) of stomach and hindgut contents was determined by oxygen bomb calorimetry. All samples were oven dried to 70-80 C before calorimetric measurements. The pre-burn (BW) and post-burn (PW) samples were weighed (mg) to determine percent combustion which represents the relative digestibility (RD) of the food (Bowen 1982) and was calculated by (Eqn. 2):

$$RD = (BW-PW)/BW \times 100 \tag{2}$$

Percent ash (A; non-digestible material) was calculated by (Eqn, 3):

$$A = PW/BW \times 100 \tag{3}$$

Non-ash (assimilable) energy (AE) was the energy contained within the digestible (burnable) portion of the sample per gram of digestible sample (Boyd and Goodyear 1971). An estimate of the assimilable energy can be determined by dividing the energy contained within a gram of total sample by the decimal percent of non-ash (1 - A/100) of the same sample or (Eqn. 4):

$$AE = \text{Energy of sample}/(1 - A/100) \qquad (4)$$

Analysis of variance was used with Scheffe's multiple comparison (SAS 1985) to test for significant differences ($\underline{P}<0.05$) of variables between lakes, among seasons, and among size groups. Correlation analysis was used to test associations of the relative digestibility of foods.

RESULTS—Macroscopic examination of blue tilapia stomach contents from Lake Alice and Lake George indicated differences in color and texture. Lake Alice blue tilapia stomach contents consisted of a dark green to brown viscous bolus of indistinguishable algae and detritus. In contrast, Lake George blue tilapia stomach contents consisted of yellowish to bright green filamentous algae and plant fragments.

ELectrofishing caused fish to swallow some of the eggs in mouth brooding females during the spring samples. Of 25 females collected from Lake Alice in April, 18 had eggs or fry in their mouths and 6 of those 18 had eggs or fry in their stomach after capture. Of the 18 brooding females, 14 had no food in their stomachs. Eight of 20 females captured in Lake George in March had eggs in their mouths and four of the eight had eggs in their stomachs after capture. Four of the eight brooding females had no food present in their stomachs. No brooding fish (fish with eggs in their mouth) or fish with eggs in their stomach were collected during other months, which suggests that spawning did not occur during other periods of the year.

Diet composition was similar between size groups for all samples. In Lake Alice, the majority of the blue tilapia diet in the fall and winter consisted of diatoms (principally *Amphora, Melosira, Navicula, Pinnularia* and *Surirella)* (Table 1). In the spring, green alga, (almost exclusively *Tetraedron*) comprised the major portion of the diet. Bluegreen algae, (almost exclusively *Phormidium*) was dominant in the summer. Small amounts of animal material (zooplankton) were found in three of the four samples. Detritus accounted for more than 25% of the material (by surface area) in the stomach in all samples

In Lake George, diet composition was also similar between size groups for all samples. Vascular plant material (exclusively *Vallisneria americana*) was prominent in all stomach samples. Green algae (principally *Oedogonium, Rhizoclonium, Tetraedron* and *Cosmarium*) were prevalent in the diet in fall

TABLE 1. Percent composition of food items in stomachs of blue tilapia from Lake Alice, October 1985 to August 1986. N = Number of pooled samples x 5 fields per sample.

Food	Fall (N=25)		Winter (N=30)		Spring (N=30)		Summer (N=35)	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Diatoms	54.0	5.1	44.0	4.2	23.2	3.1	4.7	1.7
Green Algae	11.3	2.0	11.9	4.8	44.1	5.0	1.1	0.7
Bluegreen Algae	1.2	0.8	0.0	0.0	0.0	0.0	68.2	3.4
Euglena	0.0	0.0	4.0	0.7	0.0	0.0	0.4	0.0
Vascular Plant	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Animal Matter	0.4	0.1	2.5	1.0	1.7	0.9	0.0	0.0
Detritus	32.1	4.3	37.6	5.1	31.0	4.7	25.5	3.1

and spring (Table 2). Diatoms (principally *Amphora, Cymbella, Cyclotella, Gomphonema, Navicula* and *Surirella*) comprised a major portion of the diet in the winter (sample taken in the spring run). Bluegreen algae (exclusively *Nostoc* and *Anabaena*) were prevalent in the summer. Animal material was rare or absent in all samples.

Comparison of the composition of food groups in the stomach contents versus hindgut contents indicates their food value (Table 3). Diatoms always occurred in higher percent composition in the stomach than the hindgut, suggesting the cells were digested. Digestion of diatoms was also evident by a large percentage of empty frustules in the hindgut. In most samples, a lower percent of bluegreen and green algal cells appeared to be digested, suggesting a lower digestibility compared to diatoms.

Stomach fullness values were not significantly different (P>0.05) between size groups in any sample from either lake. Fullness values were lowest during spawning months (March - April) and highest during fall samples for both lakes (Fig. 1).

No significant differences in caloric content of foods ingested were found between size groups in either lake. Therefore size groups were pooled. Average total caloric values of foods in Lake George were significantly higher than in Lake Alice except during the winter sample (Table 4). Ash content of food was significantly higher in all samples in Lake Alice than in Lake George. This resulted in correspondingly higher assimilable energy values per

TABLE 2. Percent composition of food items in stomachs of blue tilapia from Lake George, December 1985 to September 1986. N = Number of pooled samples x 5 fields per sample.

Food	Fall (N=25)		Winter (N=30)		Spring (N=30)		Summer (N=35)	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Diatoms	12.0	2.7	34.0	4.1	2.7	0.8	7.0	1.7
Green Algae	28.7	2.9	11.9	4.0	64.6	9.7	14.0	3.9
Bluegreen Algae	0.0	0.0	5.0	1.9	0.0	0.0	46.0	4.2
Euglena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vascular Plant	48.3	5.2	34.8	8.1	16.9	9.8	23.0	5.1
Animal Matter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detritus	11.0	2.1	9.3	1.4	15.9	4.7	10.0	1.2

TABLE 3. Digestion of food groups by blue tilapia in Lakes Alice and George estimated by the proportion of the food group in the stomach minus the proportion of the food group in the hindgut; (+ = more in stomach than hindgut; - = more in hindgut than in the stomach.

	Lake Alice				Lake George			
Food Component	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
Diatoms	+29.0	+33.0	+18.0	+1.7	+7.1	+33.0	+2.5	+7.0
Diatom Frustules	–35.0	–44.0	–33.0	–26.0	–24.0	–42.0	–17.0	0.0
Green Algae	–2.8	–5.7	+18.0	–3.2	+12.0	+12.0	+24.0	–21.0
Bluegreen Algae	+1.2	–0.8	0.0	+45.0	–2.7	+5.0	0.0	+46.0
Euglena	+3.8	0.0	–0.9	0.0	0.0	0.0	0.0	0.0
Vascular Plants	+0.5	0.0	0.0	0.0	+13.0	+0.5	–10.0	+18.0
Animal Matter	–1.2	–5.8	+0.3	–0.7	0.0	0.0	0.0	0.0
Detrail Matter	–2.3	+9.2	–3.2	–2.0	–6.1	+8.5	+1.0	–50.0

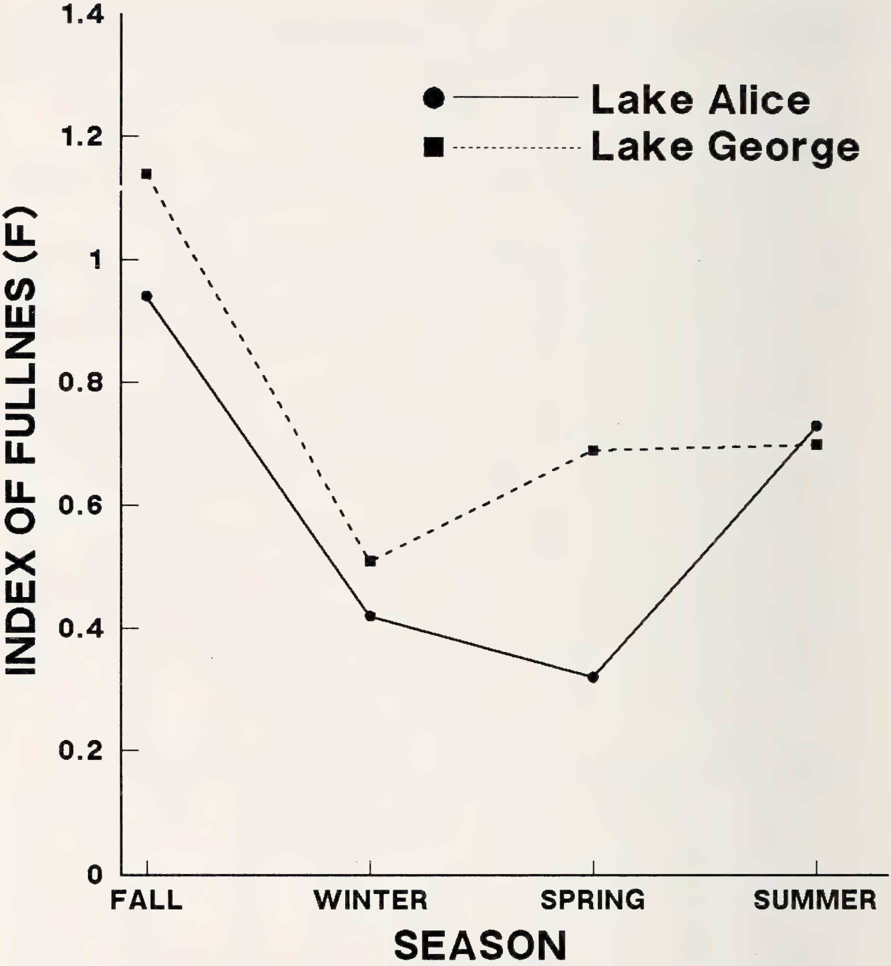

FIG. 1. Index of fullness (F) for blue tilapia in Lakes Alice and George from fall 1985 to summer 1986.

assimilable gram in Lake Alice. In Lake Alice, summer ash contents were significantly higher ($P<0.05$) than the other three samples (Table 4). In Lake George, significant differences ($P<0.05$) in ash content occurred as follows: winter > fall > spring and summer. Significant negative correlations ($P<0.05$) existed between percent ash and total caloric content in both lakes (Lake Alice, $r^2 = -0.94$; Lake George, $r^2 = -0.92$). As the ash content of the sample decreases, the amount of kilocalories/gram (dry weight) of sample increases due to the digestible nature of the food (Bowen, 1982).

DISCUSSION—The diet of blue tilapia changed seasonally and consisted of varying amounts of several algal types in Lake Alice. Because of inadequate sampling of the algal foods available, it could not be determined if the algae

TABLE 4. Total energy (kilocalories/gram dry weight), assimilable energy and percent ash of blue tilapia stomach contents from Lakes Alice and George.

Season	Total Energy kcal/gram			Assimilable Energy kcal/gram assimilable			Percent Ash		
	N	Mean	S.E.	N	Mean	S.E.	N	Mean	S.E.
				Lake Alice					
Fall	29	2.09	0.04	13	4.36	0.05	13	52.5	1.2
Winter	18	2.03	0.04	18	4.48	0.06	18	54.8	0.8
Spring	15	2.36	0.10	15	4.54	0.11	15	48.1	2.3
Summer	18	1.49	0.05	18	4.35	0.04	18	65.9	1.2
				Lake George					
Fall	22	3.04	0.05	17	4.06	0.04	17	26.7	1.6
Winter	12	2.58	0.03	12	3.92	0.06	12	34.5	1.6
Spring	18	3.32	0.02	18	4.14	0.03	18	19.6	1.1
Summer	3	3.36	0.02	3	4.03	0.01	3	16.5	0.3

ingested were planktonic or epipelic types. However, the relatively large amount of detritus present in the stomach contents suggests that algae were obtained from the lake bottom. In contrast, blue tilapia in Lake George ate primarily epiphytic algae which can be easily identified by their holdfasts attached to macrophytes (e.g. Chlorophyta: *Oedogonium*, Chrysophyta: *Gomphonema*). Epiphytes consumed were similar to those found on the macrophyte, *Vallisneria americana*. The high incidence of vascular plant material was classified as incidental because tilapia that ingest epiphytes frequently ingest some of the supporting macrophyte (Munro, 1967). The occurrence of more vascular plant material in the fall and winter was probably related to incidental ingestion of senescent plants. While feeding on epiphytic algae, tilapia probably cannot scrape as efficiently on senescent vascular plants as on healthy growing plants.

Utilization of plant material by fishes is limited by their digestive capabilities (Lobel, 1981). Most fish lack cellulase (Fish, 1960; Stickney, 1976) which is needed to digest cellulose in plant cell walls. Lysis of algal cells by gastric acidity (pH ≤ 2) has been suggested as an alternative method used by tilapia to digest these foods (Fish, 1960; Moriarty, 1973). However, whole empty diatom frustules in the hindgut suggest that acid lysis of frustules may not be necessary to obtain nutrition from diatoms. Diatoms have various slits and pores in their frustules that allows access to the cytoplasm by various enzymes (Delevoryas, 1966). This would allow diatoms to be more effectively digested than other algae once optimum stomach pH was reached for enzyme activity. This suggests the importance of diatoms to tilapia in any system.

The quantity of food ingested by blue tilapia varied seasonally in both lakes. Low food intake in the spring was likely related to decreased feeding activity of mouth brooding fish. Low food intake was also observed in the winter. Food intake of warmwater fishes decreases at low water temperatures. In Lake Alice, low food intake was expected when winter water temperatures declined below 10°C and extensive mortality attributed to low water temperatures has occurred (personal observations). However, winter food intake in Lake George was essentially the same as in Lake Alice, even though these fish were collected from a spring area where water temperatures were constant (22°C). This leads us to believe that low food intake may be related to a limited food supply resulting from the high density of blue tilapia in the thermal refuge during this time of year. As expected, food ingestion was high in the summer; but in both lakes food intake was greater in the fall than in the summer. There is no obvious environmental factor that accounts for the greater food consumption in the fall than in the summer. The greater food intake in the fall suggests that this may be the time of greatest individual growth.

Assimilable energy for plant material is usually around 4.0 to 4.2 kcals/gram dry weight plant material (Phillips, 1972). Assimilable energy values for stomach contents of blue tilapia were within this range of values in Lake George. However, values from Lake Alice were greater than 4.2 kcal/gram. Although present in relatively low amounts, zooplankton were ingested by blue tilapia and were most prevalent in the diet in winter and spring when assimilable energy values were highest in Lake Alice. Zooplankton were not ingested by blue tilapia in Lake George. Low amounts of animal material (5.0 to 6.0 kcal/gram Robbins, 1983) and could account for the higher assimilable energy values found in Lake Alice.

A high percentage of ash after combustion (relative digestibility) in a calorimeter indicates food is less digestible. The greater percentage of amorphous material and diatom frustules in Lake Alice blue tilapia diets accounts for high ash contents, thus decreasing the amount of digestible material per gram of sample. Green algae have a lower ash content than other types of algae (Montgomery and Gerking, 1980) which agrees with the low ash contents that occurred in Lake George foods.

The plant foods in Lake Alice are epipelic and/or phytoplanktonic in nature. These foods support a large biomass of blue tilapia. Although biomass has not been quantified, gillnet sampling suggests high densities of large (>1 kg fish). In the past, mortality of large tilapia (1-2 kg) due to low water temperatures has occurred, and counts of 300-400 dead fish were common. In contrast, the plant foods in Lake George are primarily epiphytic algae. Population density and biomass of tilapia appear to be much lower in Lake George than in Lake Alice. However, it is not known whether the abundance of blue tilapia in Lake George is related to the food supply or the amount of fish that can overwinter in limited thermal refuges. It is clear from the occurrence of populations of blue tilapia in these two different types of habitats that this trophically flexible fish can be expected to persist in thermally suitable habitats with sufficient growth of epiphytic, planktonic or epipelic algae.

LITERATURE CITED

Bowen, S. H. 1982. Feeding, digestion, and growth—Qualitative considerations. Pp.141-156. *In* Pullin, R. S. V. and R. H. Lowe-McConnell (eds.) The Biology and Culture of Tilapias. ICLARM Conference Proceedings 7. International Center for Living Aquatic Resources Mangement. Manila, Phillipines. 432 p.

———— . 1984. Detrital amino acids and the growth of *Sarotherodon mossambicus*–a reply to Dabrowski. Actae Hydrochim. Hydrobiol. 69:265- 270.

Boyd, C. E. and C. P. Goodyear. 1971. Nutritive quality of food in ecological systems. Arch. Hydrobiol. 69:256-270.

Buntz, J. and C. S. Manooch, III. 1968. *Tilapia aurea* (Steindachner), a rapidly spreading exotic in south central Florida. Proc. 22nd Ann. Conf. S.E. Assoc. Game and Fish Comm. 22:495-501.

Courtenay, W. R., Jr. and C. P. Robins. 1973. Exotic aquatic organisms in Florida with emphasis on fishes: A review and recommendations. Trans. Am. Fish. Soc. 102:1-12.

Delevoryas, T. 1966. Plant diversification. Holt, Rinehart and Winston, Inc. New York, NY. 145 p.

Drenner, R. W., S. B. Taylor, X. Lazzaro, and D. Kettle. 1984. Particle grazing and plankton community impact of an omnivorous cichlid. Trans. Am. Fish. Soc. 113:397-402.

Fish, G.R. 1960. The comparative activity of some digestive enzymes in the alimentary canal of tilapia and perch. Hydrobiol. 15:161-178.

Foote, K. 1977. Preliminary status investigations of blue tilapia. Annual report, Florida Game and Freshwater Fish Comm. Eustis, Florida. 46 pp.

Hendricks, M. K. and R. L. Noble. 1978. Feeding interactions of three planktivorous fishes in Trinidad Lake, Texas. Proc. 33rd Ann. Conf. S.E. Assoc. Fish Wildl. Agen. 33:324-330.

Lobel, P. S. 1981. Trophic biology of herbivorous reef fishes: Alimentary pH and digestive capabilities. J. Fish Biol. 19:365-397.

McBay, L. G. 1961. The biology of *Tilapia nilotica* Linneaus. Proc. 15th Ann. Conf. S.E. Assoc. Game Fish Comm. 5:208-218.

Montgomery, W. L. and S. D. Gerking. 1980. Marine macroalgae as foods for fishes: An evaluation of potential food quality. Environ. Biol. Fish. 5:143-153.

Moriarty, D. J. W. 1973. The physiology of digestion of bluegreen algae in the cichlid fish *Tilapia nilotica*. J. Zool. 171:25-39.

Munro, J. L. 1967. The food of a community of East African freshwater fishes. J. Zool. 151:389-415.

Phillips, A. M., Jr. 1972. Calorie and energy requirement. Pp 1-28 *In* HALVER, J.E.(ed.) Fish Nutrition. Academic Press, New York, NY.

Robbins, C. T. 1983. Wildlife feeding and nutrition. Academic Press, Inc. Orlando, FL. 343 pp.

SAS (Statistical Analysis System). 1985. SAS User's Guide: Version 5. SAS Institute, Cary, North Carolina.

Spaturu, P. and M. Zorn. 1976. Some aspects of natural feed and feeding habits of *Tilapia galilaea* (Artedi) and *Tilapia aurea* (Steindachner) in Lake Kinneret. Bamidgeh 28:12-17.

———— . 1978. Food and feeding habits of *Tilapia aurea* in Lake Kinneret (Israel). Aquaculture 13:67-79.

Stickney, R. P. 1976. Cellulase activity in the stomachs of freshwater fishes from Texas. Proc. 29th Ann. Conf. S.E. Assoc. Game and Fish Comm. 29:282- 287.

Taylor, J. N., W. R. Courtenay, Jr., and J. A. McCann. 1984. Known impacts of exotic fishes in the continental United States. Pp. 141-156. *In:* Courtenay, W. R., Jr. and J. R. Stauffer (eds.) Distribution, Biology and Management of Exotic Fishes. The John Hopkins University Press, Baltimore, MD.

Winfree, R. A. and R. P. Stickney. 1981. Effects of dietary protein and energy on growth, feed conversion efficiency, and body composition of *Tilapia aurea*. J. Nutr. 111:1001-1012.

Zale, A. V. 1984. Applied aspects of the thermal biology, ecology, and life history of the blue tilapia, *Tilapia aurea* (Pisces: Cichlidae). Technical report no. 12. Florida Coop. Fish and Wildlife Research Unit. Gainesville, FL. 196 pp.

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DISTRIBUTIONS OF FLORIDA SNEEZEWEEDS (*Helenium*), WITH A RANGE EXTENSION FOR *Helenium autumnale* L.

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ABSTRACT: *Distributions of the six species of sneezeweeds* (Helenium) *in Florida are discussed. The first record of* Helenium autumnale *L. for the Florida Peninsula and Orange County is documented.*

SIX species of sneezeweeds (*Helenium*) are found in Florida. *Helenium pinnatifidum* (Nuttall) Rydberg and *H. amarum* (Rafinesque) H. Rock occur throughout the state (Clewell, 1985, Long and Lakela, 1971, and Wunderlin, 1982). *Helenium flexuosum* Rafinesque primarily ranges in the northern half of the state (Clewell, 1985; Wunderlin, 1982) with a disjunct population in Dade County (Long and Lakela, 1976; Wunderlin, 1992). The other three species, *H. brevifolium* (Nuttall) Alphonso Wood, *H. vernale* Walter, and *H. autumnale* L., occur in the Panhandle. The listing of *H. vernale* as occurring within the geographical area covered by Long and Lakela (1971) is an error based on a misidentification of *H. pinnatifidum* (Wunderlin,1992).

While searching for flowering specimens of the corkey-stemmed passionflower (*Passiflora suberosa* L.) on 24 August 1991, three plants of *Helenium autumnale* were found on the Rock Springs Run State Reserve (RSRSR), in northwestern Orange Co., Sec. 20, T20S, R29E. The plants, in flower, grew alongside a ditch bordering the western portion of Buffalo Tram Road heading toward the Wekiva River. The community type is a wet flatwood/hardwood hammock interface. The plants were photographed and a voucher specimen was made.

A second population of *H. autumnale* (Sec. 5, T20S, R29E) was discovered in a wet flatwoods on 17 October 1991 about 2 miles N of the first population. At least six plants in full bloom grew along both sides of an unnamed service road to the west of the RSRSR shop. Photographs and a voucher specimen of this population were made.

These two populations are the first known for the species in the Peninsula and represent a range extension of about 125 miles southeast of the nearest population in Taylor County near Hampton Springs. It is unlikely that the species was introduced to Orange County because of the remoteness of the two sites in RSRSR. To our knowledge, a study of the plants of this area has never been undertaken.

Voucher specimens from the RSRSR sneezeweeds have been deposited in the herbaria of the universities of South Florida and Central Florida.

FLORIDA VOUCHER SPECIMENS OF *Helenium autumnale* L. *Calhoun Co.:* Near Clarksville, 21 Oct 1957, 76201 (FLAS). *Jackson Co.:* Near Chattahoochee, 21 Oct 1971, R. L. Lazor 5628 (FSU); E. of Sneads, 9 Oct 1978, R. K. Godfrey 76710 (FSU). *Gadsen Co.:* Near Chattahoochee, 8 Sep 1931, 24339 (FLAS); "Dodecantheon Glade," 6 Nov 1987, 166684 (FLAS);

Near Chattahoochee,18 Oct 1981, 150798 (FLAS & USF); Near old town site of Aspalaga & S of I-10 bridge, 2 Nov 1977, L. C. Anderson 4563 (FSU); Near Chattahoochee, 13 Sep 1956, R. Kral 3558 (FSU). *Liberty Co.:* W. of Bristol, 19 Aug 1968, R. L. Lazor 926 (FSU); W. of Bristol, 9 Nov 1976, R. K. Godfrey 75792 (FSU); W. of Bristol, 26 Apr 1959, R. K. Godfrey 58482 (FSU); W. of Bristol, 18 Oct 1968, R. L. Lazor 1306 (FSU); Torreya State Park, 1 Oct 1972, R. K. Godfrey 72205 (FSU). *Franklin Co.:* Old Womans Bluff, Apalachicola River, 19 Jul 1985, L. C. Anderson 8532 (FSU); N.W. of Apalachicola on C-384, 20 Sep 1984, L. C. Anderson 7634 (FSU); N.W. of Apalachicola, 29 Jun 1956, R. Kral 2750 (FSU); Crooked Crook on Rte 67, N of Carabelle, 10 &11 Aug 1968, R. K. Godfrey 67985, 90451(FSU). *Wakulla Co.:* St. Marks, 11 Oct 1960, R. K. Godfrey 52569 (FSU); Near Newport, 16 Oct 1959, R. K. Godfrey 59080 (FSU). *Taylor Co.:* 3 mi. W of Econfina River on Hwy. 90, 1 Oct 1989, 171483 (FLAS); Near Hampton Springs, 21 Oct 1960, R. K. Godfrey 60445 (FSU).

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LITERATURE CITED

CLEWELL, A. F. 1985. Guide to the Vascular Plants of the Florida Panhandle. Univ. Presses of Florida, Florida State Univ. Press, Tallahassee.

LONG, R. W. AND O. LAKELA. 1971. A Flora of Tropical Florida. Univ. of Miami Press, Coral Gables.

WUNDERLIN, R. P. 1982. Guide to the Vascular Plants of Central Florida. Univ. Presses of Florida, Univ. of South Florida Press, Tampa.

WUNDERLIN, R. P. 1992. Univ. South Florida, Tampa, Pers. Commun.

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RESPONSE OF SINGLE COMB WHITE LEGHORN HENS TO VARIOUS DIETARY LEVELS OF CROTALARIA AND NUTRIENT FORTIFICATION AS A MEANS OF ALLEVIATING DEPRESSED PERFORMANCE

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Abstract—*Two 28-day experiments were conducted with White Leghorn hens to determine whether the effect of* Crotalaria spectabilis *(Roth) was at least partially due to reduced feed intake and to examine nutrient fortification as a means of managing low-level contamination problems. Pair-fed birds performed comparably to those receiving their respective levels of seed addition. Increased dietary nutrient density was associated with significantly improved egg production at each level of seed addition. Daily feed intake was also improved for 368 and 736 mg/kg seed treatments. The mortality rate was not affected in either study. A substantial portion of crotalaria's effect appeared related to reduced feed intake, and nutrient fortification may be helpful in the management of such contamination problems.*

Crotalaria spectabilis (Roth) is probably one of the most researched weeds related to toxicity problems in the poultry and livestock industry. It is a summer annual with green erect stems that grow to 1.5 m in height. The seed pods that appear at the top of the plant, along with yellow flowers, contain kidney-shaped seed that turn shiny black at maturity.

In years past, several of the over 600 crotalaria species were extensively recommended by federal and state agricultural agencies as soil builders due to their nitrogen-fixing ability and value as green manure crops. As the livestock industry continued to develop, problems began to be recognized in animals that consumed portions of the plant or its seeds. Six, and possibly seven, species of crotalaria were subsequently identified as being toxic (Ritchie et al., 1941). The two most common species found in the Southeastern United States are *Crotalaria (C.) giant striata* (L.) and *C. spectabilis* (Roth), with the latter having been found to be the most harmful to poultry (Kelly et al., 1961). The symptoms of crotalaria poisoning in poultry have been reported by a number of groups, including Hooper and Scanlan (1977), Caylor and Laurent (1963), Halvorson (1972) and Harms and co-workers (1963). Also, the pathological changes associated with poultry's exposure to *Crotalaria spectabilis* (Roth) have been well documented by Simpson and co-workers (1963).

The authors' interest in additional studies with crotalaria developed in response to inquiries from producers who had purchased new-crop local corn containing a variety of weed seeds. Several of the papers in the literature contained information indicating that at least a portion of the seed's effect might be related to feed refusal. For example, one of the symptoms described by Hooper and Scanlan (1977) for pigs exposed to *Crotalaria retusa* (L.) was inappetence. Caylor and Laurent (1963) observed that 0.2% *Crotalaria spectabilis* (Roth) caused hens to become very emaciated due to feed rejection. Harms and co-workers (1963) found that feed conversion of broiler chicks was not significantly affected by *C. spectabilis* levels up to 282 seeds per kilogram fed from one day to four weeks of age although growth was significantly inhibited. In other words, body weight decreases were the direct result of reduced feed intake and not physiological toxicity. The authors also stated that laying pullets receiving up to 141 seeds per kilogram often rejected the feed and became emaciated. In work with *Cassia obtusifolia* (L.) seed, another common corn contaminant, Hebert and Flory (1983) concluded that the growth differences seen were probably due more to reduced feed intake than to the toxic effects of the seed.

Based on these reports, two experiments were designed to determine whether a portion of crotalaria's effect was due to reduced feed intake and to look at nutritional fortification as a possible means of managing low-level contamination problems.

METHODS—In the first 28-day experiment, four replicate groups of five individually caged 48-week old White Leghorn hens (Hy-Line W-36) received diets containing 0, 368, 736, or 1,472 mg of hand-harvested *Crotalaria spectabilis* (Roth) seeds per kilogram of diet after the seeds had been ground through a Model 4 Wiley mill (Thomas Scientific, P.O. Box 99, Swedesboro, NJ 08085-0099). These seed levels, and those of Experiment 2, were selected based on the range of concentrations employed in the work of Caylor and Laurent (1963) and Harms and co-workers (1963).

Since the later work expressed results using seed counts, several careful test weighings of 100-seed aliquots were utilized to develop treatment levels in the present experiments. The various seed amounts were added to the corn-soybean meal basal diet shown in Table 1. This diet was designed to provide the correct level of daily nutrient intake according to the recommendations of Harms and Douglas (1982). Four days after seed treatments were initiated, two additional groups of pair-fed hens began receiving daily allocations of control feed equal to amounts actually consumed by the 736 and 1,472 mg/kg seed groups. Those feed quantities were established on Tuesday and Friday of each week and started the following day.

In Experiment 2, nutrient fortification was tested as a means of mollifying the effects of crotalaria exposure. Seed levels of 368, 736 or 1,104 mg/kg were given, after grinding, in both the control and fortified diets of Table 1. The highest concentration of seed given in Experiment 1 was not repeated in Experiment 2 because the lower level results provided a response sufficient to demonstrate the tenants of the experiment. The control feed composition was again selected according to the current level of feed consumption from those recommended by Harms and Douglas (1982). Since the fortified diet was one developed for a lower level of feed intake (Harms and Douglas, 1982), the percentage increase of all nutrients was not the same. The common amino acids were elevated 19 to 24%, calcium- 15%, and the energy content was somewhat lower than in the control feed. Each treatment was provided to three replicate pens of five individually caged 48-week old White Leghorn hens for a 28-day period.

The same criteria were considered in both studies. Initial and final body weights were taken along with daily records of egg production and mortality rate. Feed intake of Experiment 2 was determined at the end of the test period. Egg weight and eggshell quality information were collected on all eggs produced. Eggshell quality was evaluated by submerging prewetted eggs in progressively more concentrated solutions of sodium chloride and water until the egg floated to the surface. The specific gravity of the solution in which flotation occurred was made a part of the data set.

The General Linear Models and Duncan's new multiple range test procedures of the SAS Institute (1982) were utilized for data analysis. For body weight change and mortality rate the model variables were treatment and replication. For the other parameters reported, treatment, replication, and week were the variables removed.

TABLE 1. Control and fortified diets for White Leghorn hens receiving graded amounts of crotalaria seed

Ingredients	Experiment 1	Experiment 2	
		Control diet	Fortified diet
	%		
Yellow corn	71.82	73.13	65.01
Soybean meal (48.5% protein)	18.71	16.38	22.62
Ground limestone	6.74	8.45	9.53
Dicalcium phosphate (18%P; 22% Ca)	1.75	1.06	1.58
Mixing salt	0.37	0.41	0.50
Microingredients[1]	0.50	0.50	0.60
Dry ML-methionine	0.11	0.07	0.16
Calculated nutrient composition[2]			
Sulfur amino acids (%)	0.63	0.56	0.71
Lysine (%)	0.77	0.70	0.88
Tryptophan (%)	0.19	0.18	0.22
Arginine (%)	1.05	0.97	1.16
Calcium (%)	3.0	3.5	4.0
Total phosphorus (%)	0.64	0.50	0.62
Metab. energy. (kcal/kg)	2,866	2,852	2,735

[1] Ingredients supplied per kilogram of diet: vitamin A, 6,600 IU; cholecalciferol 2,200 ICU; menadione dimnthylpyrimidinol bisulfite, 2.2 mg; riboflavin, 4.4 mg; pantothenic acid, 13.2 mg; niacin, 39.6 mg; choline chloride, 500 mg; vitamin B_{12}, 0.022 mg; ethoxyquin, 125 mg; manganese, 60 mg; iron, 50 mg; copper, 6 mg; cobalt, 0.198 mg; zinc, 35 mg; iodine, 1.1 mg; selenium, 0.1 mg.

[2] National Research Council (1984).

RESULTS AND DISCUSSION—In Experiment 1 (Table 2), the 736 and 1,472 mg/kg treatments produced separate significant negative effects on feed consumption as intake dropped to 66% of controls on the 1,472 mg seed treatment. Egg production was reduced for both the 1,472 mg group and the birds receiving a comparable amount of feed without seed. However, neither 736 nor 1,472 mg of crotalaria per kilogram of diet resulted in any depression of egg output beyond that connected with lower feed consumption.

Over the four-week period, egg weights were not decreased by any treatment. Conversely, birds that received the lower two seed amounts had egg weights significantly greater than untreated hens; possibly the result of reduced production intensity. As might be expected in association with reduced feed consumption, eggshell quality was significantly lower with the 1,472 mg/kg treatment and its seedless companion group. Again, this is readily explained by the depressed feed, and therefore calcium, consumption.

Hens lost progressively and significantly more body weight as seed concentration increased. Pair-fed birds lost less weight than their seed-treated counterparts. However, losses were statistically similiar for the highest seed concentration. Few deaths occurred and they were not related to treatments.

In Experiment 2, daily feed intake was reduced in both control and fortified diet series by seed addition, but fortification resulted in a significantly greater intake at 368 and 736 mg/kg seed (Table 3). Egg production on the control feed was significantly reduced by increasing crotalaria concentration. Although 368 mg/kg significantly reduced performance in the control feed,

TABLE 2. Response of White Leghorn hens to dietary crotalaria seed or pair-feeding (Exp. 1)

Crotalaria (mg/kg)	Hen-day egg prod --%--	Daily feed intake	Egg wt	Egg shell quality[1]	Body wt change 14 days	Body wt change 28 days
		------g------			------g------	
Control	70.6^{a}	102^{a}	67.2^{b}	8.86^{a}	-24^{ab}	-76^{a}
368	67.8^{a}	98^{ab}	68.8^{a}	8.61^{a}	-58^{b}	-130^{ab}
736	62.6^{a}	91^{b}	68.8^{a}	8.58^{a}	-68^{b}	-204^{bc}
1472	42.9^{b}	67^{c}	67.5^{b}	7.69^{b}	-121^{c}	-345^{d}
Pair-fed 736[2]	61.3^{a}	—	67.0^{b}	8.64^{a}	-9^{a}	-120^{a}
Pair-fed 1472[2]	48.1^{b}	—	67.3^{b}	7.10^{b}	-68^{b}	-274^{cd}

[a-d]Means without common superscripts are significantly (P < .05) different according to Duncan's new multiple range test (SAS Institute, 1982).

[1] Average container code in which egg surfaced while being moved through progressively more concentrated salt solutions. The range of possible values was 1 to 15.

[2] Treatments received same daily allocation of feed as that consumed free-choice by the respective 736 and 1472 mg/kg treatments. Allocations were established on Tuesday and Friday of each week and instituted the following day.

TABLE 3. Response of White Leghorn hens to diet fortification in the presence of dietary crotalaria seed (Exp. 2)

Crotalaria (mg/kg)	Hen-day egg prod ----%----	Daily feed intake	Egg wt	Egg shell quality[1]	Haugh units	Body wt change ---g---	Daily seed intake -----mg-----
		------g------					
			Control diet				
0	77.9^{a}	83.2^{a}	61.5	8.8^{a}	77.0^{b}	-87^{bc}	—
368	65.5^{bc}	71.5^{b}	61.6	7.5^{b}	77.4^{b}	-182^{cd}	26.31
736	59.0^{c}	63.1^{c}	61.9	7.3^{b}	81.5^{a}	-248^{d}	46.44
1104	47.4^{d}	62.3^{c}	62.7	7.6^{b}	78.3^{ab}	-260^{d}	68.78
			Fortified diet				
0	81.1^{a}	85.5^{a}	62.9	9.1^{a}	78.8^{ab}	33^{a}	—
368	79.8^{a}	83.3^{a}	62.4	9.0^{a}	78.1^{ab}	-66^{b}	30.65
736	71.5^{ab}	71.1^{b}	61.4	7.7^{b}	78.8^{ab}	-185^{cd}	52.33
1104	62.5^{bc}	63.3^{c}	61.8	8.1^{ab}	76.9^{b}	-287^{d}	69.88

[a-d]Means without common superscripts are significantly different (P< .05) according to Duncan's new multiple range test (SAS Institute, 1982).

[1] Average container code in which egg surfaced while being moved through progressively more concentrated salt solutions. The range of possible values was 1 to 15.

fortification supported production equal to both basal and fortified basal levels. The more concentrated feed also held egg production of the 736 mg/kg group to that of control and fortified basals. Eleven hundred and four mg/kg of crotalaria seed reduced feed consumption to where nutrient supplementation was inadequate to maintain egg production. Birds on the fortified diet still laid at a significantly higher rate than those getting the same amount of seed in the control feed.

In the control diet, eggshell quality was reduced by the lowest seed level (368 mg/kg). Fortification maintained shell quality at both the 368 and 1,104 mg/kg levels, but the 736 mg/kg value was lower. The authors have not been able to find an explanation for this anomaly. As in the first study, egg weights were not affected by any of the treatments.

Body weight change was significantly in favor of increased nutrient density for both the basal and 368 mg/kg groups. Weight loss of the fortified 368 and 736 mg/kg groups did not differ from that of birds receiving the control feed. The mortality rate was low and not treatment related, so it has not been reported.

Calculations of daily seed intake (Table 3) indicated that hens receiving the concentrated diets consumed slightly more crotalaria than those fed control diets even though many performance measures were enhanced by fortification.

Data are in agreement with reports of seed-related inappetence by Caylor and Laurent (1963), Harms and co-workers (1963), Hebert and Flory (1983), and Hooper and Scanlan (1977). A significant portion of crotalaria's depressing effect was related to reduced feed intake, and increased dietary nutrient density was helpful in improving layer performance. Such fortification could be useful in dealing with field seed contamination problems.

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LITERATURE CITED

CAYLOR, J. F. AND C. K. LAURENT. 1963. Effect of level of *Crotalaria spectabilis* on egg production of White Leghorn hens. Poultry Sci. 40:818 (Abstract).

HALVORSON, D. 1972. Crotalaria poisoning - a case report. Pp. 15-16. In: Rosenwald, A.S. (eds), Proc. 21st Western Poultry Diseases Conf., Univ. of Calif., Davis, CA.

HARMS, R. H. AND C. R. DOUGLAS. 1982. Feeding Commercial Laying Hens. Fl. Coop. Ext. Ser. Info. Series 82-2, Univ. Florida, Gainesville, FL 32611-0721.

———, P. W. WALDROUP, AND C. F. SIMPSON. 1963. Effect of feeding various levels of *Crotalaria spectabilis* seed on the performance of chicks, turkeys, and pullets. J. Am. Vet. Med. Assoc. 142: 260-263.

HEBERT, C. D. AND W. FLORY. 1983. Determination of the oral toxicity of *Cassia obtusifolia* seeds in chickens. Vet. Hum. Toxicol. 25:164-166.

HOOPER, P. T. AND W. H. SCANLAN. 1977. *Crotalaria retusa* poisoning of pigs and poultry. Austral. Vet. J. 53:109-114.

KELLY, W., C. W. BARBER, D. D. PATE, AND H. HILL. 1961. Effect of feeding crotalaria seed to young chickens. J. Am. Vet. Med. Assoc. 139: 1215-1217.

NATIONAL RESEARCH COUNCIL. 1984. Nutrient Requirements of Poultry. 8th rev. ed. National Academy Press, Washington, DC.

RITCHIE, G. E., R. MCKEE, R. B. BECKER, W. M. NEAL, AND P. D. ARNOLD. 1941. Crotalaria for Forage. Univ. of Fl. Agr. Exp. Sta. Bull. 361, Gainesville, FL 32611-0721.

SAS INSTITUTE. 1982. SAS User's Guide: Statistics. SAS Institute, Inc., Cary, NC.

SIMPSON, C. F., P. W. WALDROUP, AND R. H. HARMS. 1963. Pathologic changes associated with feeding various levels of *Crotalaria spectabilis* seed to poultry. J. Am. Vet. Med. Assoc. 142: 264-271.

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SOIL VACUUM EXTRACTION, AN ENGINEERING CONTROL TO LIMIT VOLATILE CHEMICAL INHALATION

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Abstract: *This article describes the use of a soil vacuum extraction (SVE) as an engineering control to limit worker exposure to volatile chemicals; the method was applied during the excavation of contaminated soils. SVE was used at a manufacturing facility located in the subtropics during the construction of a concrete spill containment area. During the initial phase of construction, workers uncovered contaminated soils that released elevated concentrations of volatile organic chemicals and hydrogen sulfide gases. Under normal conditions, personal protection equipment that deliver either bottled or clean ambient air would have been used by site workers to complete construction. In contrast, soil gases were intercepted with wells that were screened above the water table, pumped through an explosion proof blower, and discharged downwind. As a result, gas concentrations were dramatically reduced and the work was completed without the aid of respiratory equipment.*

Compliance with occupational safety and health requirements can be difficult in subtropical and tropical regions of the United States. The day-long use of either Level B or Level C personal protection equipment (Table 1, Department of Health and Human Services, 1985) at temperatures in excess of 90°F can be injurious because workers generate and retain excess body heat and radiant energy (Goldman, 1983; Shapiro et.al, 1981). As a result, workers potentially exposed to hazardous conditions are reluctant to wear respiratory and dermal protection devices because heat stress often poses a greater risk to health than direct exposure to contaminated media.

The Hazardous Waste Operations and Emergency Response Rule 29 CFR 1910.120, Section l (Department of Labor, 1989), provides for the use of engineering devices to limit employee exposure. Besides the use of pressurized cabs, control booths, and remotely controlled equipment, however, few engineered controls are used routinely. This article describes the use of soil vacuum extraction (SVE) as an engineering control to limit worker exposure to volatile chemicals; the method was applied during the excavation of contaminated soils.

Level D personnel protection (Table 1) was used during soil excavation because a SVE system intercepted the subsurface volatile chemicals through vacuum wells before they were released to ambient air. Under normal circumstances, either Level C or Level B personal protection could have been selected for several reasons: (1) volatile chemical concentrations exceeded the permissible exposure limits (PELs), (2) hydrogen sulfide is poorly absorbed by activated carbon filters used in air-purifying respirators, and (3) organic gases can irritate mucous tissues and the skin (Department of Labor, 1989, Sittig; 1985).

TABLE 1. Personal Protection Levels and Equipment

Level of Protection	Protection Equipment
B	RECOMMENDED:
	o Pressure-Demand, full-facepiece SCBA or pressure-demand supplied-air respirator with escape SCBA.
	o Chemical-resistant clothing (overalls and long-sleeved jacket; hooded, one- to two-piece chemical splash suit; disposal chemical-resistant one-piece suit).
	o Inner and outer chemical-resistant gloves.
	o Chemical-resistant safety boots/shoes.
	o Hard hat.
	o Two-way radio communications.
	OPTIONAL:
	o Coveralls.
	o Disposable boot covers.
	o Face Shield.
	o Long cotton underwear.
C	RECOMMENDED:
	o Full-facepiece, air purifying canister-equipped respirator.
	o Chemical-resistant clothing (overalls and long-sleeved jacket; hooded, one- or two- piece chemical splash suit; disposable chemical-resistant one-piece suit).
	o Inner and outer chemical-resistant gloves.
	o Chemical-resistant safety boots/shoes.
	o Hard hat.
	o Two-way radio communications.
	OPTIONAL:
	o Coveralls.
	o Disposable boot covers.
	o Face shield.
	o Escape mask.
	o Long cotton underwear.
D	RECOMMENDED:
	o Coveralls
	o Safety boots/shoes.
	o Safety glasses or chemical splash goggles.
	o Hard hat.
	OPTIONAL:
	o Gloves.
	o Escape mask.
	o Face shield.

The application of vacuum extraction to limit worker exposure is innovative. In addition to limiting worker exposure, the technique saves money because it accelerates project completion, lessens the possibility of heat stress, and does not require additional training as is necessary when using a self-contained breathing apparatus (SCBA) or inline respiratory protection device.

The gaseous transport and removal efficiency of a SVE is directly influenced by geological conditions. In general, porous lithologies with either high percentages of sand, gravel, or karst limestone pose favorable conditions for SVE; silt, fine sand, and clay can pose conditions less favorable for SVE. To determine whether gaseous transport and removal efficiency was appropriate for SVE, a radius of influence test was conducted.

Site Background—As part of a plant maintenance program at a Caribbean site, soil excavation was required to construct a spill pad for a tanker- unloading platform and drum-cleaning area. The spill pad was constructed to avoid the further losses of aromatic solvents to the soil and ground water. The excavation was dug with pick and shovel and without the aid of heavy equipment so as to avoid puncture of subsurface conduits.

Releases of aromatic hydrocarbons (benzene, xylene, toluene, ethylbenzene) had occurred at the site's solvent recovery facility. As a result of hydrocarbon losses and conditions favorable for anaerobic bacterial growth in the subsurface, hydrogen sulfide gas was produced at concentrations 5 orders of magnitude greater than its odor threshold (5 ppb) (Sax and Lewis, 1989). A soil and ground-water investigation confirmed that both soil and ground water were contaminated (Moon et al., 1991). Odor surveillance reports and a soil-gas survey conducted previously by Geraghty & Miller indicated that a large subsurface excavation would liberate noxious odors and gases at concentrations that would require respiratory protection.

The excavated area was unobstructed on three sides and positioned above consolidated limestone. The depth to water was approximately 20 ft. A solvent-recovery facility was contiguous with the proposed excavation; the facility was operational throughout the construction period.

MATERIALS AND METHODS—The pilot study estimated that a minimum of a 50-ft radius would be induced by a SVE well. This study was conducted by drilling three SVE wells; the second and third wells were located 25 ft and 50 ft respectively from the first. Each SVE well was drilled to a depth of 15 ft below land surface and constructed with 2" diameter, Schedule 40 PVC; two feet of casing was allowed to remain above land surface. The bottom of the screened interval was placed several feet (5 ft) above the top of the water table. Well screens, 5 ft in length (0.10 inch slot size) were placed vertically 10-ft below land surface (bls) to 15 ft bls. One SVE well (test well) was fitted with a regenerative blower (Rotron, 5 hp) and the remaining wells were fitted with PVC caps and magnahelic gauges (Dwyer). Vacuum measurements were recorded from each SVE well after a flow-rate of 50 standard cubic feet per minute (SCFM) was extracted for 15 minutes.

Test results showed vacuum measurements of 1 inch and 0.5 inches of water respectively, at the two SVE wells located 25 ft and 50 ft from the test well. These measurements corresponded to a 50 ft or greater radius of influence.

Multiple SVE wells may not be required to evaluate SVE efficiency and applicability. In some instances, shallow piezometers, rather than additional SVE wells, may be used to measure the horizontal extent of influence created by the SVE well. This approach was successfully used at an adjacent part of the site. When using shallow piezometers, however, it is important not to allow the introduction of ambient air through the annular space of the piezometer during vacuum measurements.

Based on the test results, two SVE wells (constructed as described above) were drilled 50 ft apart and located approximately 13 ft outside of the most contaminated part of the excavation. The wells were connected by a common header with 2" PVC pipe and attached to a blower (Rotron, 2.5 hp). The blower was attached to a vertical PVC pipe (20 ft high) located downwind and approximately 100 ft from the construction area (Fig. 1). A wind sock was placed at the top of the vertical exhaust pipe to provide a visual indication of wind direction.

The breathing zone was monitored throughout 17 days of construction with a Jerome H_2S Analyzer (hydrogen sulfide) and a Photovac TIP (ionizable gases). A total of eight air sample measurements were collected each day in the breathing zone (4 to 6 ft above land surface): four samples were collected in both the morning and afternoon hours. Morning and afternoon air-sample measurements were recorded and averaged separately each day.

RESULTS—Measurements of H_2S and total volatiles showed significantly lower airborne concentrations in the breathing zone during SVE operation

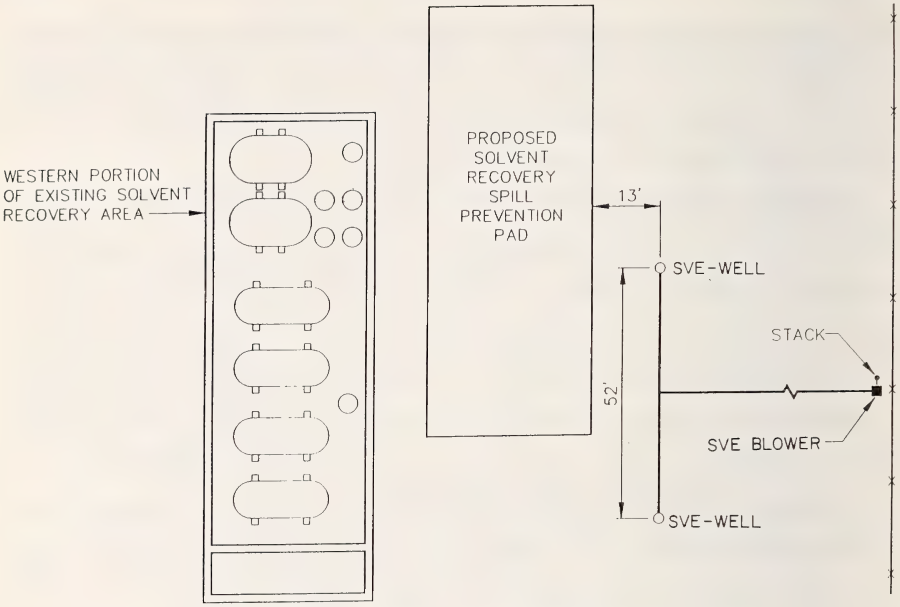


FIG 1. Schematic diagram of solvent recovery extraction and discharge system.

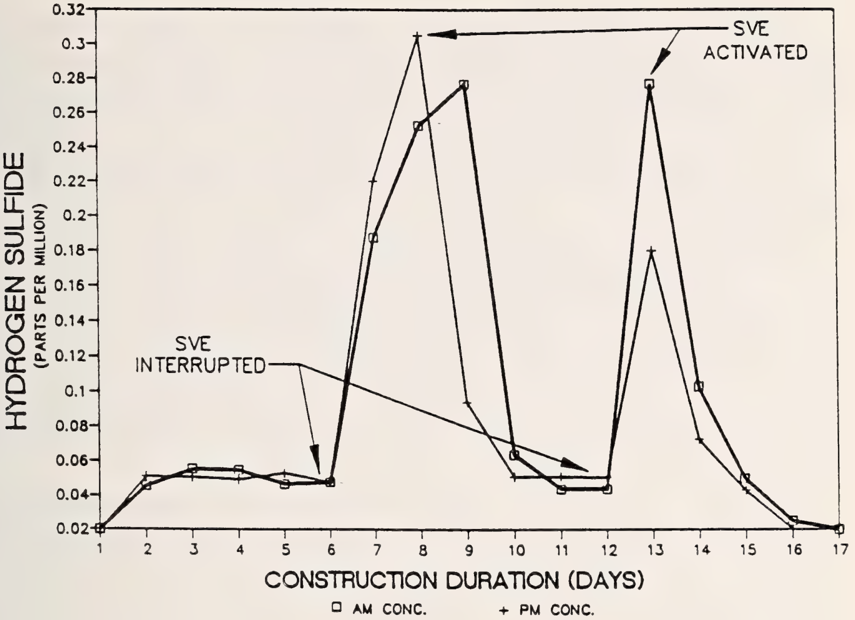
when compared with nonoperational periods. (Fig. 2). On two occasions, when the blower was either temporarily removed or after an electrical power loss, H_2S and total volatile concentrations were observed to increase immediately after the SVE was interrupted.

During SVE operation, H_2S concentrations were measured between 0.040 to 0.060 parts per million (ppm). These concentrations are approximately 8 to 12 times higher than the odor threshold for H_2S (5 ppb). After 2 days of SVE interruption, H_2S concentrations increased approximately 6-fold to 0.30 ppm.

Although the H_2S concentrations remained below the PEL (10 ppm) during SVE interruption (Department of Health and Human Services, 1990), air samples collected in the work area contained H_2S concentrations 75 times that of the odor threshold limit.

Total volatile concentrations ranged between 80 and 100 ppm during SVE operation. These measurements indicate that the combined airborne concentration for individual chemicals did not exceed the permissible exposure limit (PEL) provisions (U.S.DHHS, 1990). Within 1.5 days of SVE disruption, organic chemical concentrations increased to concentrations that were 8-fold higher and ranged from 500 ppm to 800 ppm. During the periods of SVE disruption, site construction continued with site workers using Level B personal protection equipment.

A comparison between air sample measurements obtained during the morning and afternoon hours showed parallel responses. Airborne concentrations varied and may have decreased slightly in response to wind speed and direction, while some increases may have been contributed by fugitive volatile chemicals from operations.



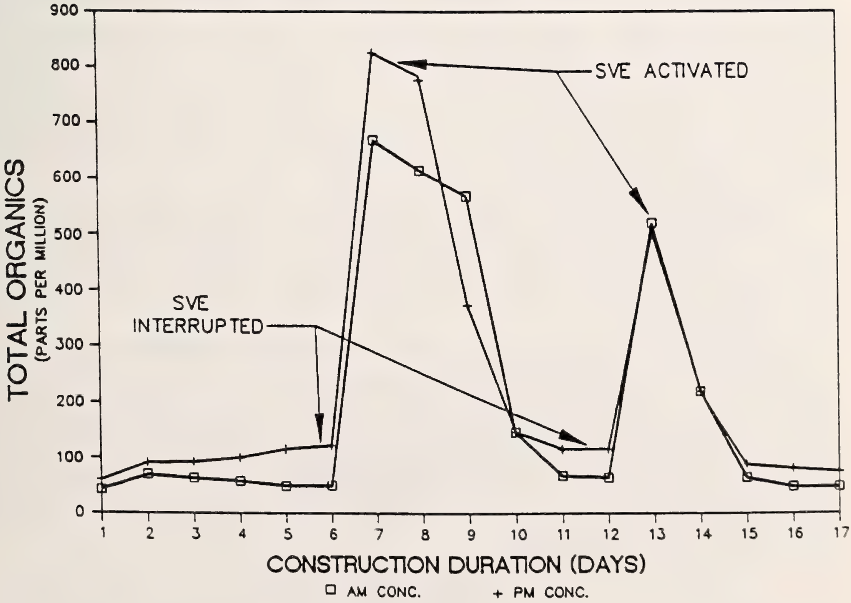


FIG 2. Total volatile organic and hydrogen sulfide monitoring results.

Discussion—Application of vacuum extraction for safety and health protection is not appropriate at all work sites; geological, regulatory, and occupational constraints may restrict its use. The efficiency of vacuum extraction at the excavation site described above was ideal; as a result, the release of volatile chemicals was remarkably diminished. In less porous conditions, additional wells and closer spacing may be required to satisfy personal protection criteria.

There are other limitations depending on state and federal regulations that may require treatment of the SVE effluent. Under some circumstances, air modeling and risk assessment may be necessary to estimate the inhalation risk posed to nearby residential populations from the SVE effluent stack. Occupational safety and health representatives may also voice concern about SVE performance criteria. Because SVE may limit the possible selection of personal protection levels A and B, air monitoring and protective measures should be required to avoid dermal contact and ingestion.

In addition, rain will temporarily seal surface soils and increase the vacuum on a SVE system. This can result in the extraction of water into the SVE through the well screen and raise the blower and exhaust temperatures. Ground water can also be extracted from the water table into the SVE well. For this reason, it is necessary to calculate the potential elevation and frictional losses of the water table before placing the SVE well. Potential harm to the blower can be avoided by installing and air/water separator on the vacuum side of the blower.

Effluent from the SVE can pose a potential explosive hazard. An efficiently designed SVE may extract volatile chemical concentrations that could be ignited by either open flames, sparks, or nonexplosion proof blowers. For this reason, explosimeter measurements on the SVE influent and exhaust should be incorporated into the site safety and health plan. Should the SVE system begin to operate below acceptable performance criteria, personal protection equipment should be available for use.

Soil type and moisture content will also influence the efficiency of an SVE system. Consolidated materials, soils with high silt and/clay content, and saturated soils will restrict the horizontal effectiveness of the system and potentially prohibit its use.

Despite these limitations, an SVE system can save money when used in the appropriate circumstances. Before construction, it was estimated that the labor, training, and personal protection equipment costs would have added an additional $10,000 to the cost of the project. Had the SVE been operational throughout the excavation, it was estimated that it could have been completed in 10 days rather than 17 days. Without SVE, the excavation would have required 24 days to complete.

LITERATURE CITED

Department of Health and Human Services (DHHS), 1990. Pocket Guide to Chemical Hazards, National Institute of Occupational Safety and Health, Public Health Service, Washington, D.C.

DEPARTMENT OF HEALTH AND HUMAN SERVICES, Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, October 1985, Publication No. 85-115.

DEPARTMENT OF LABOR, OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION, 29 CFR 1910. 1989. Hazardous Waste Operations and Emergency Response: Final Rule. Washington, D.C.

GOLDMAN, R.F. 1983. Heat Stress in Industrial Protective Encapsulating Garments. Contract deliverable to U.S.Department of Health and Human Services, Order No. 83-211.

MOON, R. E., R. ACKART, J. A. WHITEHEAD, AND K. A. CHELLMAN. 1991. Soil-Gas Remediation of Reduced Sulfur Compounds in a Limestone Aquifer. Pg. 431-442. *In*: TEDDER, D. W. (ed.). Proc. First Annual Hazardous Materials and Environ. Manage. Conf./South, Hazmat 91'South. Tower Conference Management Co., Glenn Ellyn, Illinois.

SAX, I. AND R. J. LEWIS, Sr. 1989. Dangerous Properties of Industrial Materials. ed. 7. Van Nostrand Reinhold, New York, NY.

SHAPIRO, Y., K. B. PANDOLF, B. A. AVELINI, N. A. PIMENTAL, AND R. F. GOLDMAN. 1981. Heat balance and heat transfer in men and women exercising in hot-dry and hot-wet conditions. Ergononics 24:375-386.

SITTIG, M. 1985. Handbook of Toxic and Hazardous Chemicals and Carcinogens, ed. 2, Noyes Publications, Park Ridge, NJ.

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VEGETATION ANALYSIS OF A HARDWOOD HAMMOCK IN DADE COUNTY, FLORIDA: CHANGES SINCE 1940

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Abstract: *A 90 by 10 m transect was established through Castellow Hammock in Dade County, Florida. All woody stems greater than 2 cm DBH were measured, identified and mapped. Average basal area, frequency and density data were compared with values from the same hammock obtained in 1940 and 1965. The data suggest some species are in decline, particularly* Bursera simaruba, Coccoloba diversifolia, Lysiloma bahamensis, *and* Mastichodendron foetidissimum. *Other species, most notably* Exothea paniculata, Nectandra coriacea, Prunus myrtifolia *and* Simarouba glauca *appear to have stable populations in the hammock.*

The flora of extreme southern Florida is largely derived from the Caribbean with a small North American component. This unique flora is seriously threatened with destruction due to development, drainage, and competition from exotic introductions. Unfortunately, few long-term ecological studies have been conducted in the islands of hardwood forests, called tropical hammocks, which grow in the Keys and on higher ground in the Everglades and south Florida. This study was undertaken to assess changes in the vegetation of a tropical hammock during the forty-five years since it was first studied (Phillips, 1940) and since a subsequent study in 1965 (Alexander, 1967).

Methods—Castellow Hammock is a 30 ha Dade County Park roughly 35 km southwest of Miami. The hammock is one of the few remaining hardwood hammocks in southern Florida outside of the Everglades National Park. The vegetation of the hammock has been previously described (Phillips, 1940; Alexander, 1967).

A transect was established in October 1986 in order to characterize the present vegetation of the hammock and to look for changes in the vegetation in the past 45 years. Phillips (1940) described the vegetation from one 150 x 2 m transect. Alexander (1967) used 16 5 X 5 m quadrats in his study, 8 in the hardwood hammock and 8 in the pineland transition zone. For this study a transect was established 140 m long and 10 m wide running from the approximate center of the hardwoods in a randomly chosen direction to the pineland transition zone. All tree stems were mapped and identified; the stem diameter at 1.3 m above the ground (DBH, diameter at breast height) was recorded for all stems greater than 2 cm DBH. The interior 90 m of the transect was used to describe the hardwood hammock vegetation; beyond 100 m, species characteristic of the pine transition zone (Alexander, 1967) appeared in the transect.

Relative dominance and density were calculated by the methods described by Cottam and Curtis (1956). In order to compare these data with those of Alexander (1967) the transect was divided into 36 5 X 5 m quadrats, and data from these areas were used to calculate average basal area per 25 m^2. Values for frequency (F = the percentage of 5 X 5 m quadrats with at least one individual of the species) and density (D = average number of individuals of a species per quadrat) were calculated as described by Alexander (1967).

To examine possible trends in the vegetation, frequency histograms were plotted by size class (DBH) for the eight most common tree species. Comparing the relative numbers of small individuals and larger, reproductive individuals can suggest if populations are stable, growing, or declining.

Nomenclature follows Long and Lakela (1971).

RESULTS—On the 90 m of transect in the hardwood hammock, *Nectandra coriacea, Simarouba glauca,* and *Prunus myrtifolia* comprised over 55% of all stems greater than 2 cm DBH (Table 1). *Bursera simaruba and Lysiloma bahamensis* comprised over 30% of the total basal area on the transect (Table 1) due to a few very large individuals on the transect.

Basal area per quadrat for the four dominant species in 1967, *L. bahamensis, B. simaruba, Coccoloba diversifolia,* and *M. foetidissimum,* was substantially lower in 1986. (Table 2).

TABLE 1. Results of the vegetation analysis of a 90 X 10 m transect in a hardwood hammock in south Florida.

Species	Relative Density*	Relative Dominance**
Nectandra coriacea	21.9	9.65
Simarouba glauca	20.0	12.67
Prunus myrtifolia	15.5	12.14
Coccoloba diversifolia	8.4	2.14
Solanum erianthum	7.7	1.02
Exothea paniculata	5.8	5.48
Bursera simaruba	3.2	25.43
Lysiloma bahamensis	1.9	8.49
Quercus virginiana	1.3	5.81
Dipholis salicifolia	1.3	0.15
Drypetes lateriflora	1.3	0.07
Other species (pooled)	9.7	0.84

*(# stems per species/total # stems) X 100. Total number of stems = 155.
**(Species basal area/total basal area all species) X 100. Total basal area = 27577 cm^2.

TABLE 2. Average basal area (cm^2) per 25 m^2 of dominant tree species at Castellow Hammock: a comparison of data collected in 1965 with data collected in 1986.

SPECIES	BASAL AREA	
	1965*	1986**
Lysiloma bahamensis	530	123
Bursera simaruba	286	195
Coccoloba diversifolia	207	16
Mastichodendron foetidissimum	130	65
Simarouba glauca	123	97
Nectandra coriacea	66	74
Prunus myrtifolia	52	93
Exothea paniculata	23	42

* Based upon eight 5 X 5 m quadrats (Alexander 1967).
**Based upon thirty-six 5 X 5 m quadrats (this study).

Values for F and D obtained in this study were compared with the values Alexander obtained for 1967 and 1940 (derived by Alexander from Phillips's data) (Table 3). The following species had substantial decreases in frequency and density: *P. myrtifolia, C. diversifolia, B. simaruba, L. bahamensis, M. foetidissimum, Q. virginiana, Dipholis salicifolia, Drypetes lateriflora, Chrysophyllum oliviforme,* and *Alvaradoa amorphoides.* Three species exhibit roughly equivalent values over time: *N. coriacea, S. glauca,* and *Exothea paniculata. Solanum erianthum* is the only species substantially more numerous in 1986.

C. diversifolia (N=18) is represented almost entirely by small individuals, while *B. simaruba* (N=5), *L. bahamensis* (N=4) and *M. foetidissimum* (N=3)

TABLE 3. Frequency (F) and density (D) values for tree species at Castellow Hammock. Values for 1986 calculated in same fashion as used by Alexander (1967) for the 1965 and 1940 values.

Species	1940		1965		1986	
	F	D	F	D	F	D
Nectandra coriacea	100	1.3	100	8.7	61	0.94
Simarouba glauca	42	0.4	100	4.1	58	0.86
Prunus myrtifolia	75	1.2	38	0.9	36	0.67
Coccoloba diversifolia	100	1.3	100	19.1	28	0.36
Solanum erianthum	8	0.1	—	—	17	0.33
Exothea paniculata	25	0.3	50	0.4	19	0.28
Bursera simaruba	58	1.9	50	0.6	14	0.14
Lysiloma bahamensis	67	0.7	63	1.0	8	0.08
Mastichodendron foetidissimum	25	0.3	25	0.3	8	0.08
Quercus virginiana	25	0.3	—	—	6	0.06
Dipholis salicifolia	42	0.3	—	—	6	0.06
Drypetes lateriflora	42	1.2	—	—	6	0.06
Chrysophyllum oliviforme	17	0.2	38	0.6	3	0.03
Alvaradoa amorphoides	17	0.3	25	1.2	0	0.00

are represented largely by older individuals and few young plants (Fig. 1). *E. paniculata* (N=13), *N. coriacea* (N=40), *P. myrtifolia* (N=25), and *S. glauca* (N=39) have size class distributions more typical of stable populations (Fig. 2).

DISCUSSION—Of the ten most common tree species found on the transect (Table 2), eight were species which Phillips (1940) and Alexander (1967) considered characteristic of the interior of the hammock. One of the exceptions, *Q. virginiana* is included here only on the basis of two large individuals in the ten meters closest to the pine transition on the transect. The other exception, *S. erianthum*, is discussed below.

E. paniculata, N. coriacea, and *P. myrtifolia* showed small increases in average basal area between 1965 and 1986 (Table 2). Meanwhile, *B. simaruba, C. diversifolia, L. bahamensis*, and *M. foetidissimum* showed decreases in average basal area in the same period (Table 2). Similar decreases in frequency and density are shown in Table 3. Differences between the 1986 data and the earlier studies could result from several factors, including changing trends in vegetation composition.

Measures of basal area can be strongly inflated by the presence of a few extremely large individuals. However, the decreases of *C. diversifolia* and *L. bahamensis*, I believe, represent real decreases and are not sampling artifacts. By choosing the eight quadrats in the 1986 data with the greatest basal area of *L. bahamensis* and *C. diversifolia*, values of 58 cm^2/m^2 and 473 cm^2/m^2, respectively were obtained; both below Alexander's values. As basal area can be strongly affected by a few large individuals, frequency and density measures might give a better indication of changing trends.

The frequency (F) and density (D) values (Table 3) confirm substantial decreases in *B. simaruba, C. diversifolia*, and *L. bahamensis*. They also suggest declines in *A. amorphoides, C. oliviforme, D. salicifolia*, and *M. foetidissimum* since 1940. Conversely, *E. paniculata, N. coriacea, P. myrtifolia*, and *S. glauca* show little change in F and D. The only species which may have increased numerically is *S. erianthum*, a weedy species that grows in disturbances. Some methodological differences between the studies might be expected to produce uniform changes across all species, suggesting the observed decreases are due to real trends or due to placement of sample plots among patchily distributed trees.

The size distributions (Figs. 1 and 2) corroborate the trends suggested by the basal area, frequency and density data. No individuals 2 cm < DBH < 14 cm of *M. foetidissimum*, *B. simaruba*, and *L. bahamensis* were found on the transect. This suggests these species are failing to establish as young plants. Conversely, *C. diversifolia* was represented by small, non-reproductive saplings: 67% of all stems were in the smallest size class and 85% less than 8 cm DBH (Fig. 1). This suggests that *C. diversifolia* has a large stock of saplings in the hammock but that few are surviving to maturity. Phenological observations (pers. obs.) indicate there were few reproductively active individuals in the hammock. While these size distributions or the basal area, F, and D values do not conclusively demonstrate species decline on their own, together they strongly suggest real decline.

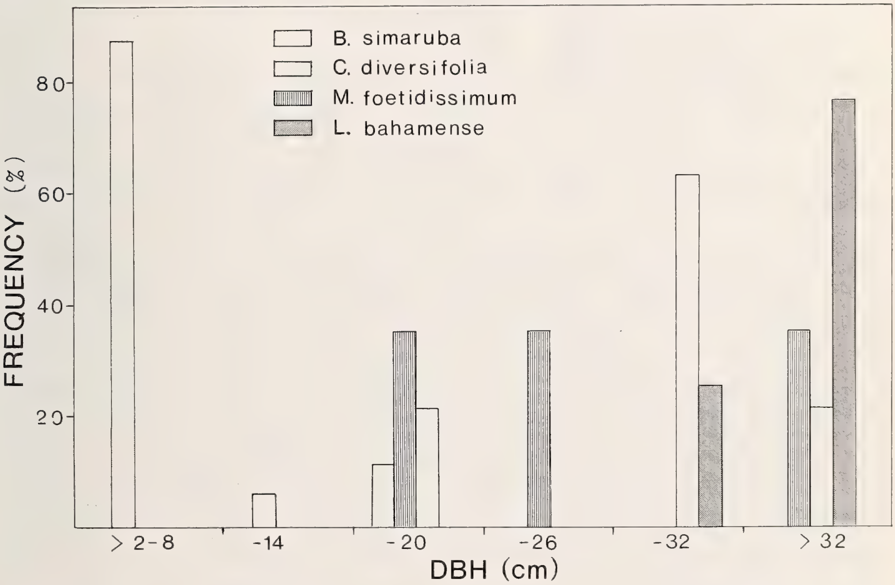

FIG. 1. Size-frequency histogram for four woody species that may be in decline in Castellow Hammock. Correction added in proof: *L. bahamense* = *L. bahamensis*.

E. paniculata, *N. coriacea*, *P. myrtifolia*, and *S. glauca* have distributions suggesting stable, re-generating populations (Fig. 2). All have vigorous populations of non-reproductive saplings as well as large, reproductive trees. The F and D values (Table 3) for these species tend to corroborate stable populations.

These data suggest some members of the unique hardwood association of south Florida's hammocks are in decline. Due to development in south

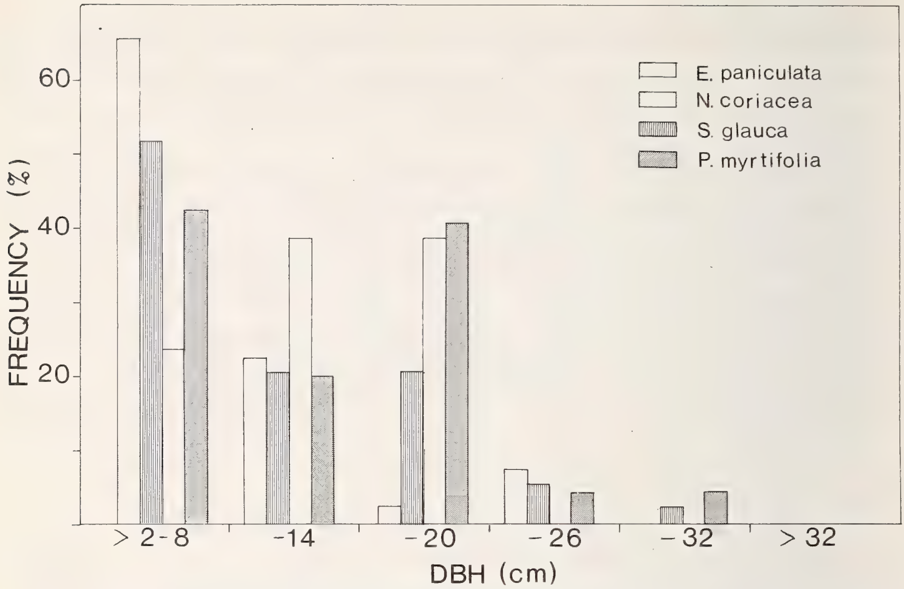

FIG. 2. Size-frequency histogram for four woody species that appear to have stable or growing populations in Castellow Hammock.

Florida, natural hammock vegetation is rare, confined to a few pockets and parks. Several possible factors might explain the decline of native species within a preserved park such as Castellow Hammock. Reduction of the population of plants outside the park might upset pollination systems and reduce fecundity of those plants remaining within the park (Janzen, 1983). Additionally, increased competition from introduced exotics might make it difficult for some native species to persist in Castellow Hammock (Stefano and Fisher, 1984; Doren and Whiteaker, 1990). Agricultural practices, such as the spraying of pesticides and herbicides, and the lowering of the water table for irrigation might also have detrimental effects on the vegetation of Castellow Hammock.

More study should be made of the natural regenerative cycles of native south Florida hardwoods. Particular attention should be given to the role of hurricanes and human disturbance in the life histories of native hardwoods.

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LITERATURE CITED

ALEXANDER, T. 1967. A tropical hammock of the Miami (Florida) limestone—a twenty-five year study. Ecology 48: 863-867.

DOREN, R. F. AND L. D. WHITEAKER. 1990. Effects of fire on different size individuals of *Schinus terebinthifolius*. Natural Areas J. 10: 107-113.

COTTAM, G. AND J. T. CURTIS. 1956. The use of distance measures in phytosociological sampling. Ecology 37: 451-460.

JANZEN, D. H. 1983. No park is an island: increase in interference from outside as park size decreases. Oikos 41: 402-410.

LONG, R. W. AND O. LAKELA. 1971. A flora of Tropical Florida. University of Miami Press, Miami.

PHILLIPS, W. S. 1940. A tropical hammock of the Miami (Fla.) limestone. Ecology 21: 166-175.

STEFANO, J. S. AND R. F. FISHER. 1984. Invasion potential of *Melaleuca quinquenervia* in southern Florida. Forest Ecology and Management 7: 133-141.

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OBITUARY

Pierce Brodkorb, 1908-1992

Dr. (William) Pierce Brodkorb, University of Florida Professor Emeritus of Zoology, passed away quietly July 18 in Gainesville. He received his A.B. from the University of Illinois (l933) and Ph.D.in zoology from the University of Michigan (1936). He was associated with various museums from 1930 to 1946, when he joined Florida as an assistant professor of zoology, becoming a full professor in 1955. He was internationally known and honored because of his contributions and his publications: the monumental five-part **Catalogue of Fossil Birds,** a standard work in paleornithology, and **Vertebrates of the United States** (which he co-authored), and more than 170 other publications. He described at least l87 bird taxa, mostly fossil forms, and at least l6 taxa were named for him by admiring colleagues. He was professionally active in many organizations. He was a dedicated supporter of the Florida Academy of Sciences, serving as Editor of the **Quarterly Journal** from 1963 to 1972. As a teacher-scholar-scientist, his impact was far-reaching, because he was much sought after as a major professor, and many of his graduate students have become leaders in paleontology and ornithology. Our loss is mitigated by the knowledge of his contributions and the pleasure of having known him.

Environmental Chemistry

AQUASHADE®, AN ANNOTATED BIBLIOGRAPHY

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ABSTRACT: *Aquashade®, a deep blue liquid, is a commercial product sold for the purpose of managing submersed aquatic plants. The annotated bibliography summarizes literature pertinent to the chemistry, toxicology, and mode of action.*

THIS bibliography is the result of enquiries we received earlier in 1992 for information on the properties of Aquashade®. As a consequence, we initiated a literature search, and the bibliography of pertinent items is annotated following this section.

This material is a deep blue liquid mixture of two food dyes, acid blue 9 and acid yellow 23 (Spencer, 1984b; cf Wilson, 1977), and it is sold by Aquashade, Inc. (Eldred, NY). It is sold for the purpose of controlling aquatic plants through light reduction (cf. Wilson, 1977). Aquashade, Inc. was required to submit data to the U.S. Environmental Protection Agency (E.P.A.) to prove that Aquashade® was effective and without harm to the environment; as a consequence, the product is registered with the U.S. E.P.A. and in all states (Wilson, 1992)

The spectrum of Aquashade® was recorded and reported by Osborne (1979). It has an absorbance maximum at about 630 nm.

There is no reported evidence that the mixture is toxic to algae (cf. Boyd and Noor, 1982; Spencer, 1984a,b). The effect of growth reduction is achieved indirectly through shading, i.e., reduction of light required for photosynthesis.

Manker and Martin (1984) recognized the possibility of two mechanisms of action: shading as indicated previously or photodynamic action. The latter is the light-lethal effect of colored substances, e.g. dyes, capable of converting ordinary oxygen (triplet) into the reactive form called singlet oxygen (an excited form of dioxygen that is 37 kcal/mole above the ground state of ordinary oxygen). Diagnostic tests were performed that should have detected the effect of singlet oxygen, and no evidence was found for its presence. In addition all available evidence supported the shading effect. Specifically, light was passed through flasks containing varying amounts of Aquashade® into flasks containing hydrilla [*Hydrilla verticillata* (Royle)] sprigs. The only light that the hydrilla in 10% Hoagland's could receive was through the dye solution, and the hydrilla was not in direct contact with the dye.

Spencer (1984a) also provided good evidence that shading was the mechanism responsible for growth limitation. He was able to elegantly demonstrate that the effect was due to reduction of light available to photosystem II light-harvesting pigments.

The component dyes of the commercial mixture are food colors. They are believed to be non-toxic to mammals at the recommended application levels, based upon feeding studies that used dogs, mice, and rats (Radomski, 1974).

As noted earlier, there was good evidence that Aquashade® was not directly toxic to hydrilla (Manker and Martin, 1984), and that inhibition of growth was a consequence of shading.

Also, as noted, Boyd and Noor (1982) reported the dye mixture seemed to have little effect on phytoplankton communities of catfish ponds.

Spencer (1984b) apparently provided the first evidence that a crayfish, widely distributed through the eastern United States was not adversely affected by the dose of Aquashade® recommended for aquatic plant control.

BOYD, C. E. AND M. H. M. NOOR. 1982. Aquashade treatment of channel catfish ponds. North Am. J. Fish. Manage. 2:193-196.
[Aquashade® seemed to have little effect on phytoplankton communities of several shallow catfish ponds.]

BUGLEWICZ E. G. 1972. The impact of reduced light penetration on a eutrophic farm pond. Masters thesis, Univ. Nebraska. Lincoln. 97 pp.
[Potamogeton spp. were eliminated by application of either blue or brown dyes, whereas *Chara* spp. were controlled only by the blue dye. (Cited by Spencer, 1984a)]

GOING, W. L. AND R. B. PURDUE. 1985. Aquatic weed control with Aquashade: A case history. Abstract, 25th Ann. Meet. Aquatic Plant Manage. Soc. 21-24 July, 1985. Vancouver, B.C.
[" Adirondack Lake. a shallow, 215-acre impoundment situated in the Adirondack Mountains of upstate New York, has been infested with broad-leafed pondweed, *Potamogeton amplifolius*, for approximately 40 years. In 1983, an estimated 70 percent of the water surface was covered with the floating leaves and stems of this plant. For years the Town of Indian Lake, New York, had attempted to control the growth of this plant through cutting/harvesting, 2,4-D applications, and overwinter drawdown, but had met with very little success. In early May of 1984, Clean Lakes Incorporated was contracted to apply 350 gallons of Aquashade, a registered herbicide which is in fact a dye, to the lake for lakewide aquatic plant control. It was intended that Aquashade would suppress photosynthesis in the submerged plants by reducing the penetration of red light. It is estimated that the plant biomass was reduced by more than 75 percent in 1984, and the majority of the plants grew no more than 36 inches tall in the impoundment, which averages 7 feet in depth."]

MANKER, D. C., AND D. F. MARTIN. 1984. Investigation of two possible modes of action of the inert dye Aquashade on hydrilla. J. Environ. Sci. Health. A19(6): 725-733.
[Mechanisms of action investigated were shading and photodynamic action." Available data indicate that the effect of shading is the major, if not exclusive, mode of action."]

OSBORNE, J. A. . 1979. Use of Aquashade to control the reinfestation of hydrilla after herbicide treatment. Aquatics 1(4):14 - 15.
[Spectrum of material in photosynthetically active region is provided. Aquashade® absorbed most strongly at 600-650 nm. A 0.41- ha pond in Orlando was treated with Aquashade® after treatment with a herbicide. By keeping concentration of Aquashade® at 3 ppm over the course of a year, the occurrence of hydrilla decreased steadily.]

RADOMSKI, J. L. 1974. Toxicology of food colors. Ann. Rev. Pharmacol. 14: 127-137.
[Acid blue 9 and acid yellow 23 are food colors and are believed to be non-toxic to mammals, based upon feeding studies with rats, mice, and dogs.]

SPENCER, D. F. 1984a. Influence of Aquashade on growth, photosynthesis, and phosphorus

uptake of microalgae. J. Aquat. Plant Manage. 22: 80-84.
[Species of algae in 50-mL batch cultures studied in contact with 1-3 ppm Aquashade®: *Anabaena flos-aquae, Anabaena cylindrica, Ankistrodesmus falcatus* var. *acicularis, Pediastrum tetras, Selenastrum capricornutum.* Results indicate that Aquashade® controls plant growth by competing with photosynthesis II pigments; material was not directly toxic to plants studied. "Blue and blue-green algae appear to be equally affected."]

———. 1984b. Oxygen consumption by the crayfish *Orconectes propinquus* exposed to Aquashade®. Bull. Environ. Contam. Toxicol. 33: 373-378.
[Oxygen uptake rates (ug/min/g fresh weight) were measured for crayfish in tapwater or tapwater with Aquashade(R) (5,10, 15 ppm) at one, three, and five days. "Oxygen consumption rates for individual *O. propinquus* exposed to Aquashade® were not significantly different from those measured for control organisms.... Based upon the data presented here Aquashade® applied at the recommended rate (1 ppm) should not significantly alter the oxygen uptake rates of *Orconectes propinquus*.... this is the first published report which suggests that Aquashade® does not adversely affect common aquatic invertebrates."]

White, M. P., T. Hypensteel, and C. A. Lembi. 1975. Evaluation of a water-soluble dye for aquatic weed control. Proc. North Central Weed Control Conf.30:171.
[" Aquashade® decreased growth of 4 species of submersed plants." (Cited by Spencer, 1984a)]

Wilson, B. 1992. President, Aquashade, Inc., P. O. Box 198, Eldred, NY 12732. Pers. Commun.

Wilson, C. G. 1977. Method for controlling the growth of aquatic plants. U.S. Patent 4,042,367. Off. Gaz. U. S. Pat. Off., 961, 1240.
[Claim 1. "A method for controlling the growth of aquatic plants in a body of water, said method comprising coloring said water with a pigment of predominantly blue color which absorbs predominantly light of a wavelength around 6500 Angstroms used by said plants for photosynthesis, at a time prior to maturity of said plants, by applying said pigment to said water in an amount sufficient to effectively arrest the growth of said plants, and repeating said coloring step, during the growing season for said plants, with a frequency directly related to the length of the growing season for said plants." Plus six additional claims.]

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FROM THE EDITORS:

This Journal has had a long, pleasant association with our printer, first with Storter Printing Company, Inc., then with StorterChilds Printing Company. Mr. Morris Storter assumed a special interest in This Journal starting with Volume 29, issue 1 in 1966. Since then, he or his firm was associated with about six editors, and each of us valued the association with him, his son-in-law, Mr. John Childs, with Ms. Laura Cook, and with a noted proofreader, "kh". Mr. Storter retired after a long, distinguished career, and last year, passed away. Now, because of economic needs for focus on a narrower product line, the **Florida Scientist** will no longer be published by StorterChilds Printing Company. A 27-year association should not go unremarked, and we are grateful on behalf of our members and our readers for the dedication to quality and accuracy, for support, and encouragement that association represented.

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It is a pleasure to acknowledge the service, dedication, and cooperation of the following persons who generously contributed their time and expertise in reviewing manuscripts for Volume 55 of the Florida Scientist. Some kindly reviewed more than one manuscript.

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ADDRESS follows the author's address.

ABSTRACT—All manuscripts shall have a short, concise, single-paragraphed abstract. The abstract follows immediately the author's address.

ACKNOWLEDGMENTS are given in the body of the text preceding immediately the Literature Cited section.

LITERATURE CITED section follows the text. Double-space every line and follow the format in the current issue.

MANUSCRIPTS of 5 or less, double-spaced typewritten pages should conform to the short article protocol. See recent issue for proper format of both long and short articles.

TABLES shall be typed on separate sheets of paper, double-spaced throughout. Each table shall contain a short heading. Do not use vertical rulings. Maximum character width, including spaces, of tables is 98.0. This includes a minimum space of 5 characters between columns. Tables are charged to authors at $45.00 per page or fraction.

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55th ANNUAL MEETING

FLORIDA ACADEMY OF SCIENCES

MAY 9-11, 1991

SAINT LEO COLLEGE
Saint Leo, Florida

Florida Scientist

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Program Issue

JUN 21 1991

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Supplement 1

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1991 PROGRAM ISSUE

THE 55th ANNUAL MEETING

FLORIDA ACADEMY OF SCIENCES

held in conjunction with the

Florida Section of the
American Association of Physics Teachers

and the

Southeastern Marine Mammal Stranding Network

Plenary Addresses:

1990 MEDALIST INVITED LECTURE:

"LIGHTNING RESEARCH IN FLORIDA"

Dr. Martin Uman
University of Florida

"QUALITY IN ACADEMIC AND RESEARCH INSTITUTIONS: CONCEPTS AND IMPLEMENTATION"

Dr. John Hadjilogiou
Florida Institute of Technology

FLORIDA SCIENTIST

Volume 54 Supplement 1

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WELCOME

Fred Buoni, 1990-91 President

Welcome to the fifty-fifth annual meeting of the Florida Academy of Sciences. The Academy strives to provide a forum for the scientists of Florida to discuss their work and to foster an environment within the State of Florida for the development and growth of science. In addition to the many special sessions sponsored by the Sections and associated organizations of the Academy, we are presenting a Plenary Address on how to build "Quality" programs in science within our research and educational institutions. In a broad sense, "Quality" programs in "Quality" institutions will ensure a growth of students for our educational institutions and increased productivity from our research programs. We need your assistance to bring "Quality" into science in Florida.

MEETING INFORMATION

LOCATION

Saint Leo College is located in the town of Saint Leo between Dade City and San Antonio. The 170 acre campus borders Lake Jovita, a large spring-fed lake, rolling hills and richly wooded grounds. Saint Leo College is Florida's oldest 4-year, residential and coeducational Catholic liberal arts college. The College was founded in 1889 by the Order of Saint Benedict, which in 1969 transferred title and control to a governing Board of Trustees. The curriculum is organized into 6 divisions, including Natural Science and Mathematics. The College is on State Road 52, east of Interstate 75, about 30 miles north of Tampa and the nearest commercial airport.

REGISTRATION

All participants are expected to register. A registration desk will be open in the lobby of Selby Auditorium from 7:30 am to 4:00 pm on Friday May 10 and from 8:00 am to 9:30 am on Saturday May 11. The registration fee is $15.00 for FAS members, $20.00 for nonmembers, and $5.00 for students. Members receive the program issue by mail, as will others registered by April 1, 1991. Extra programs cost $4.00.

LODGING

No reservations can be made through the Academy. The following hotels are closer to Saint Leo than any others but are still 12-23 miles from campus. Round trips from campus to these hotels will take 30 minutes to an hour depending on traffic, road and weather conditions. All require a credit card number or one night prepayment for reservations.

BEST WESTERN: 1304 Gall Boulevard, Zephyrhills, FL 33540
(813:782-5527). Twelve miles from campus on U.S. 301. No dining room, but restaurants nearby. Daily rate for one person: $36.00; two persons: $38.00. Guarantee late arrival after 1600 hours.

DAY'S INN: 15010 Highway 54 West, Zephyrhills, FL 33543
(813:973-0155). Twelve miles from campus on I-75 and S.R. 54. Dining room (Denny's) open 24 hrs. Daily rate for one person: $30.00; two persons: $35.00. Guarantee late arrival after 1800 hours.

HOLIDAY INN: 30307 Cortez Boulevard, Brooksville, FL 34602
(904:796-9481). Seventeen miles from campus on I-75 and S.R. 50. Dining room open 0600-2200 hrs. Daily rate for one person: $45.00; two persons: $50.00. Guarantee late arrival after 1800 hours.

RAMADA INN: 400 East Bearss Avenue, Tampa, FL 33613
(813:961-1000). Twenty-three miles from campus on I-75 and Bearss Avenue. Dining room open 0630-1400 and 1700-2200 hours. Daily rate for one person: $35.00; two persons: $40.00. Guarantee late arrival after 1600 hours.

MEALS
The College cafeteria will be open for all meals: breakfast, 7:00-9:00 AM; lunch, 12:00-1:00 PM; dinner, 5:00-6:00 PM.

BANQUET
The Academy Social and Banquet will be held on Friday evening, May 10, 1991 at the McDonald Student Center overlooking Lake Jovita. The cash bar Social will begin at 6:30 PM and the Banquet will begin at 7:15 PM. Dinner will be buffet style and will consist of shrimp cocktail, tossed salad with dressing, grilled chicken, baked fish, potato, vegetables, assorted desserts and beverages. Cost will be $15.00 including gratuity. Participants should preregister for the banquet, since only a limited number of tickets will be available at registration.

After dinner, the 1990 Academy Medalist, Dr. Martin Uman, will offer a banquet address "LIGHTNING RESEARCH IN FLORIDA". The William W. Behrens, Jr./Florida Institute of Oceanography Award will be presented and other Academy honors will be bestowed. The Banquet Program will conclude with the installation of the new Academy President, Dr. George Dooris.

COUNCIL MEETING
The Executive Committee and Academy Council will meet at 7:00 pm on Thursday May 10, 1991, in the McDonald Student Center.

ANNUAL BUSINESS MEETING
The Academy's annual business meeting will begin at 1:15 pm on Friday in the Selby Auditorium. Members of the Executive Committee and Chairs of sections and standing committees are asked to bring written 1990-1991 reports.

PLENARY ADDRESSES
Two quality lectures in University Research will be offered to the Academy at large.

1. Quality in Academic and Research Institutions: Concepts and Implementation. Dr. John Hadjilogiou, Head, Department of Electrical and Computer Engineering, Florida Institute of Technology, Melbourne, FL

2. Lightning Research in Florida. Dr. Martin Uman, University of Florida, Gainesville, FL (1990 MEDALIST INVITED LECTURE).

INFORMATION FOR SPEAKERS
All rooms have slide projectors and screens. Speakers wishing to use transparencies (overhead slides) should verify with their session chair that one will be provided for that session. Speakers requiring special equipment must contact the chair of the local arrangements committee. Student speakers should identify themselves to the session chair prior to speaking.

All posters will be presented after the afternoon sessions on Friday, May 10, from 4:30 until 6:00 pm. Posters must be installed before the afternoon session begins.

If an author or co-author is scheduled to speak but cannot attend due to unforseen circumstances, arrangements should be made for a colleague to present the paper. If a reader cannot be found, the paper should be canceled. The Academy must be notified of a substitute speaker or cancellation, by contacting the appropriate section chair.

ANNOUNCEMENTS

MARINE MAMMAL STRANDING NETWORK The Network meeting is scheduled for 10:00 am to 12 noon on Saturday, May 11, 1991. The meeting will include a review of marine mammal strandings in the southeastern United States, with specific reference to Florida events of the past year, as well a presentations and discussions on other marine mammal stranding topics. A necropsy demonstration is planned for Saturday afternoon. Persons wishing to attend should contact Dr. Daniel K. Odell, Sea World of Florida, (407) 363-2158.

Persons registered for the FAS Annual Meeting may attend the Network meeting on a space-available basis. Network members wishing to attend FAS sessions are asked to register, but may attend the afternoon Plenary Address as FAS guests.

SOUTHERN ASSOCIATION/HABITAT ARTISTS There will be a wildlife habitat show presented by the Southern Association/Habitat Artists in the Hazel Whitman Lounge in the McDonald Student Center on May 10 and 11. The hours will be 10:00 am to 7:30 pm on Friday and 10:00 am to 5:00 pm on Saturday.

Displayed works by the Association will be originals and limited edition prints representing environmentally endangered species and habitats.

LOCAL ARRANGEMENTS Meeting arrangements at Saint Leo College are coordinated by George Dooris, chair of the Local Arrangements Committee, who may be consulted on any aspect of meeting support, including special services, by calling (904) 588-8339.

PUBLICATION The 1991 Annual Program Issue, is Supplement Number 1 to Volume 54 of the Florida Scientist, and will be distributed to more than 200 domestic and foreign libraries as well as major abstracting services.

ACKNOWLEDGEMENTS The Academy thanks CONNECTICUT VALLEY BIOLOGICAL SUPPLY COMPANY, P. O. Box 326, Southampton MA 01071, for providing two generous door prizes for the banquet.

The Academy expresses its thanks and appreciation to HDR Engineering, Inc. for providing the coffee and donuts on Friday and Saturday morning to those attending the Annual Meeting.

EXHIBITS:

Lewis Hall Registration Area
Friday and Saturday
Connecticut Valley Biological Supply
Space Academy USA

PROGRAM SUMMARY

THURSDAY EVENING, MAY 9, 1991

7:00	FAS Council Meeting	McDonald Student Center

FRIDAY MORNING, MAY 10, 1991

7:30	Registration (to 4:00 pm)	Selby Lobby
8.00	Geological and Hydrological	Lewis 113
9:00	Agricultural Science	Lewis 203
	Anthropology *	Lewis 305
	Biological Science, Session A *	Lewis 205
	Biological Science, Session B	Lewis 207
	Science Teaching *	Lewis 303
9:30	Computer Science and Mathematics *	Lewis 307
10:15	Social Sciences *	Lewis 119

FRIDAY AFTERNOON, MAY 10, 1991

1:15	Academy Meeting	Selby Auditorium
2:00	Plenary Address I	Selby Auditorium
3:00	Rare and Endangered Biota (FCREPA) *	Lewis 303
	Biological Science, Session C	Lewis 205
	Biological Science, Session D	Lewis 207
	Anthropology B	Lewis 307
	Physics and Space Science *	Lewis 203
	Science Teaching *	Selby Auditorium
4:30	Poster Session	First Floor, Lewis Hall

FRIDAY EVENING, MAY 10, 1991

6:30	Academy Social Hour	McDonald Student Center
7:30	Banquet	McDonald Student Center
8:30	Plenary Address II	McDonald Student Center

SATURDAY MORNING, MAY 11, 1991

7:30	AAPT Breakfast *	Saint Leo College Cafeteria
8:00	Registration (to 9:30)	Selby Lobby
9:00	Environmental Chemistry/Chemical Science *	Lewis 303
10:00	Marine Mammal Stranding Network	Lewis 205
	Medical Sciences *	Lewis 207
10:15	Engineering *	Lewis 203
	AAPT, Session A	Selby Auditorium

SATURDAY AFTERNOON

1:00	AAPT, Session B	Selby Auditorium

* Section Business Meeting to follow this session

AGRICULTURAL SCIENCE

Friday, 9:00 am – 10:00 am, Lewis Hall 203
SESSION A
G.M. Prine, University of Florida, Presiding

9:00 am, AGR–1A Errors in the Weight Estimation of Horses by Veterinarians and Lay Horsemen. J. KIVIPELTO (1), R.L. ASQUITH (1), E.L. JOHNSON (1), AND C. DEPEW (2), (1) Department of Animal Science, 459 Shealy Drive, Gainesville, Florida 32611, (2) Extension Department, 226 Knapp Hall, Louisiana State University, Baton Rouge, Louisiana 70803. This study evaluated the proficiency of horsemen and veterinarians in estimating the weight of equines using only visual appraisal. Five groups of veterinarians and/or lay horsemen estimated the weights of five equines of various ages, sexes and breeds. The equines were individually weighed on a large-animal scale prior to trial. The 253 horsemen and veterinarians participating in these trials averaged 15 years of experience working with horses and indicated that they routinely estimated the weights of horses when determining appropriate feed and medication dose levels. Eight percent of the weight estimations recorded were underestimations of the actual weight of the horses. The average underestimation per horse was 166 lb, or 16% of the average total body weight per horse. These results indicate that underestimating the weight of a horse is a common error.

9:15 am, AGR–2A Nematode Population on Basil, Oregano, and Sage in a Naturally Infected Florida Sandy Soil. J.E. MORENO (1), E.C. FRENCH (1), G.M. PRINE (1), R.A. DUNN (2), AND J.R. RICH (3). Respectively, Agronomy and Entomology and Nematology Departments, IFAS, Univ. of Florida, Gainesville 32611. A field study was conducted to determine the numbers and kinds of plan parasitic nematodes associated with basil, oregano, and sage. For one growing season, monthly soil samples were collected and nematodes counted. Results showed that populations of plant parasitic nematodes increased as the season progressed with a maximum peak in the summer months and decreased by the end of the season. *Meloidogyne* spp. was the most common and the one that increased the most in basil, oregano and sage. With the exception of *Xiphinema americanum*, few plant parasitic nematodes were associated with oregano.

9:30 am, AGR–3A The Influence of Varied Stem Maturity on Rooting of L. *micromera* and L. *graveolens*. J.R. ESPAILLAT, E.C. FRENCH AND S.H. WEST, University of Florida, Institute of Food and Agr. Sci., Dept. of Agronomy, Gainesville, Florida 32611. Different stages of vegetative maturity influence rooting potential of stem cuttings. Oregano is in high demand in the international herb market. The objective of this study was to determine optimum stem maturity stage for cutting propagation of Caribbean (*Lippia micromera* S.) and Mexican (*Lippia graveolens* H.) oreganos. Three Randomized Complete Block experiments with 4 replications were performed. Hardwood main stems, hardwood secondary stems, softwood stem tips, and semi-hardwood stem tips were placed upright in perlite using a hotbed. Bottom heat temperature was 28°C for all experiments. At 23 days, shoot growth (SG), and root length (RL) ratings and rooting percent data were taken. Shoot growth and RL showed significant differences. Softwood stem tips resulted in greater SG and RL followed by semi-hardwood stem tips.

9:45 am, AGR-4A Field Fertilization Trials of Selected Spices. S.H. ANGELL (1 E.C. FRENCH (1), P.E. HILDEBRAND (2), W.G. BLUE (3), AND E.B. WHITTY (3). (Department of Agronomy, University of Florida, Gainesville 32611, (2) Department of Foc and Resource Economics, University of Florida, Gainesville 32611, (3) Department of Sc Science, University of Florida, Gainesville 32611. Dry Matter Yield (DMY) is one of sever important factors to consider in developing spices as a commercial field-grown crop. Th objective of the experiments conducted with 8 spices is to determine the effect of N an K (alone and in combination) on the DMY of the spices. Field fertilization trials wer established at the University of Florida involving 4 levels of N and 3 levels of K in complete factorial design. Regression analysis of DMY indicate that spices respond mo favorably to additions of 168 and 252 Kg N ha^{-1} in combination with 168 Kg K ha^{-1} alone, depending on the specie. Plants responded poorly to K treatments when not combination with N. Poorest yields were recorded when no fertilizer was added acros all species.

10:00 am, BREAK

Friday, 10:15 am - 11:30 am, Lewis Hall 203
SESSION B
K.H. Quesenberry, University of Florida, Presiding

10:15 am, AGR-5B Energy Crops have Potential on Phosphatic Settling Por Clays. G.M. PRINE (1), D.B. SHIBLES (2) AND J.A. STRICKER (2), (1) University Florida, Agronomy Department, Gainesville, FL 32611 and (2) Mined Lanc Research/Development Project, Bartow, FL 33830. Leucaena (Leucaena leucocephal and tall perennial grasses sugarcane and energycane (Saccharum sp.) and elephantgras (Pennisetum purpureum), grow better on the reclaimed settling pond clays in Centr Florida than on other mineral soils. These crops can be harvested each winter followir growth of 9 months or longer. The biomass produced can be used for direct burnin conversion to methane or fuel alcohol or extracted into various chemical components f making plastics, resins and other products. Sewage sludge and/or effluent from Tamp Lakeland and other nearby cities could be used to fertilize energy crops. Sweet sorghu (Sorghum bicolor) and sugarcane can be grown for ethanol production. Sweet sorghu could be harvested in September and October and sugarcane from late October until th first killing freeze. Juice extracted from sorghum and cane can be processed into ethan directly or evaporated to syrup for later processing.

10:30 am, AGR-6B Growth Performance of Full-Season Elephantgrass ar Energycane in North-Central Florida. K.R. WOODARD AND G.M. PRINE, Department Agronomy, IFAS, University of Florida, Gainesville, FL 32611. A 2-year bioma experiment was initiated in 1989 to study the uninterrupted growth of elephantgra (Pennisetum purpureum Schum.) and energycane (Saccharum spp.) during the 8- to month warm-growing season in north-central Florida. Included were two t elephantgrasses (PI 300086, N51), a tall energycane (L79-1002), and an intermedia pearlmillet X elephantgrass hybrid (Selection 41). Harvests were made at 28-d interva beginning 16 May (day 49) and ending 29 November (day 245) during 1989 and 199 Average annual dry matter yields over the two years were 45.0, 47.6, and 38.8 Mg h yr^{-1} for PI 300086, N51, L79-1002, and Selection 41, respectively. Two-year mean crop growth rates during the linear growth phases were 24, 24, 23, and 22 g m^{-2} d^{-1} of dry biomass, respectively. Average linear growth phases lasted for 178, 192, 182, and 178 days, respectively. The high-yielding capability of these bunchgrasses was related to the long linear growth phase.

10:45 am, AGR-7B Leucaena, Energy and Forage Crop for Florida. T.V. CUNILIO AND G.M. PRINE, University of Florida, Agronomy Department, Gainesville, FL 32611. Leucaena (Leucaena leucocephala) is a small tree in the tropics but is an annual-regenerating, perennial legume shrub in subtropical Florida. The topgrowth is killed by freezes of less than 30°F and the plant regrows from below ground parts. Best adapted to well-drained soils, well-established leucaena can produce stems weighing over 30 Mg ha^{-1} dry biomass annually. The stems can be harvested annually or the dead stems can stand for a year and new live stems develop so that two-year's growth can be harvested at one time. When managed as forage (stems below 6 mm in size plus leaves cut 3 or 4 times a year) dry matter yields up to 10,000 kg ha^{-1} have been obtained. Leucaena can be browsed by cattle on a rotational basis and stockpiled for use in dry fall. A review of literature on leucaena in subtropics and selected biomass yields, persistence, vigor, and pest resistance of the selected accessions from over 300 leucaena entries planted in 1979 will be reported.

11:00 am, AGR-8B Effect of growth regulators on *in vitro* bud formation and shoot elongation in desmodium. P.A. KROTTJE, D.S. WOFFORD, AND K.H. QUESENBERRY, Agronomy Department, IFAS, University of Florida, Gainesville 32611. Desmodium (*Desmodium spp.*) is a self-pollinated, perennial legume with considerable potential for use as a forage crop in Florida and the humid subtropics. Current *in vitro* regeneration protocol for desmodium consists of sequential treatments for callus growth, bud induction, and shoot elongation. This work aimed at improving the efficiency of the bud and shoot steps through manipulation of growth regulator level and treatment duration. For the bud nduction step, calli were treated with 0.1, 0.3, 1.0, or 3.0 mg L^{-1} 2,4-D for periods of 0, 3, 7, 14, or 28 days. Treatments for the shoot elongation step were 28 days on 0.2, 0.6, or 2.0 mg L^{-1} benzyladenine (BA) with either 0 or 0.1 mg L^{-1} gibberellic acid (GA). Maximum bud production was observed with 1.0 or 3.0 mg L^{-1} 2,4-D for 14 or 28 days. However, prolonged exposure to the higher 2,4-D level appeared to inhibit subsequent shoot elongation. Interaction effects between levels of BA and GA in the shoot elongation medium will be presented.

1:15 am, AGR-9B Epidemiology of cylindrocladium root rot in white clover. ALVARO AMAYA, D.S. WOFFORD, K.H. QUESENBERRY, AND D.A. ROBERTS, Agronomy Department, IFAS, University of Florida, Gainesville, 32611. *Cylindrocladium crotalariae* (Loos) Bell and Sobers, a soil-borne fungus, has been shown to infect numerous legume species. In Florida, observations of red clover, alfalfa, and white clover ndicate that this fungus is a virulent pathogen on these forage legumes. An experiment o study the epidemiology of *C. crotalariae* on white clover was established in fall 1990. Six plant introduction lines of white clover previously evaluated for resistance under greenhouse conditions were included in this study. Two of these lines are considered esistant, two moderately resistant, and two susceptible. Entries were planted in single row plots of fifteen plants in a randomized complete block design. Disease incidenc collected on weekly intervals, will be expressed as the number of live plants in relation the total number of plants. Disease progress curves (incidence vs. time) will be generate and appropriate growth models fitted to aid in the analysis and interpretation of th genotypic response.

Friday, 11:30 am, Lewis Hall 203
BUSINESS MEETING: AGRICULTURAL SCIENCES
E.C. French, presiding

ANTHROPOLOGICAL SCIENCES

Friday, 9:00 am – 10:30 am, Lewis Hall 305
SESSION A: Water, Earth, Stars
Leslie Lieberman, University of Florida, Presiding

9:00 am, ANS-1A Maritime Anthropology: What's the Use? MICHAEL JEPSO Department of Anthropology, University of Florida, Gainesville, 32611. Continuir changes in management plans for both Florida's commercial and recreational fisheri due to depletion of stocks and environmental degradation signal a complex problem th requires an interdisciplinary approach. One aspect of this approach includes regul gathering and analysis of socio-cultural data. With increase study of fisheries and fishir communities, maritime anthropologists have devised innovative and reliable methods th can facilitate and enhance policy formation. Specific methods and roles for maritim anthropologists, such as delphi panels, focus groups, and culture broker are part of th quantitative and qualitative mix of methods that are typical of anthropology, and shou contribute an added dimension to management of Florida's fisheries.

9:15 am, ANS-2A How Can We Get Where We're Going If We Don't Know Whe We Are?: A Map Survey. KATHI KITNER AND STEPHEN KRZYSZTON, Department Anthropology, 1350 TUR, University of Florida, Gainesville, 32611. The authors prese the results of a survey of geographical (map) knowledge of University of Floric undergraduates. Preliminary analysis of the data indicates a continuing decline geographical knowledge, as well as a difference in comprehension between females ar males. The impact of the U.S. news media on students' geographical awareness is als discussed. We conclude with recommendations on how to improve student geographical consciousness.

9:30 am, ANS-3A Impact of El Nino Flooding on Prehistoric Agricultural Southern Peru, D.R. SATTERLEE, Department of Anthropology, University of Floric Gainesville, 32611. A strong El Nino-Southern Oscillation (ENSO) phenomenon can slc the rotation of the earth, alter the length of day, impact global climate, and crea worldwide disasters (Salstein and Rosen, 1984). The 1982-83 El Nino caused the dea of 10,000 people. Recent LFC (Large Format Camera) photos show an even more destructive prehistoric ENSO event in the Moquegua drainage of southern Peru. From May through August, 1990, research was conducted in the Moquegua Valley to assess the El Nino flood damage to the irrigated, terraced agricultural system of the indigenous Chiribaya Culture. Volcanic ash, ice core data, and C-14 samples were used to correlate the dates of two ancient flood events.

10:00 am, ANS-4A Precolumbian American Astronomy: Implications for the Field. STEPHEN S. KRZYSZTON, Department of Anthropology, 1350 TUR, University of Florida, Gainesville, 32611. Evidence from the young fields of archaeoastronomy and ethnoastronomy indicates that astronomical knowledge in the precolumbian Americas was extensive (if not pervasive) and more advanced than that of Europe. The author presents a brief survey of early American astronomy, and especially highlights the accomplishments of the Mayans, Incas and Anasazi. The paper concludes with a discussion of the implications this knowledge holds for present and future archaeological fieldwork in the Americas.

0:15 am, ANS-5A Burr Heybe, Somalia: Understanding How The Geological Forces Influenced Cultural Development. KATHLEEN UMLAND, University of Florida, Department of Anthropology, 1350 Turlington Hall, Gainesville, 32611. Burr Heybe potters are considered to be the best potters in Somalia. They began potting between 7,000 and ,000 years ago and the archeological record shows few technological changes from the beginning of potting to present. However, new evidence taken from X-ray fluorescent spectrometer analysis, hydrometer analysis, and X-ray diffraction has brought to light information about its geological properties which help to explain the technological history of Burr Heybe potters.

riday, 10:30 am
ECTION MEETING
eslie Lieberman, presiding

riday, 3:00 pm – 5:00 am, Lewis Hall 307
ESSION B: Medical Anthropology: Focus on Women

:00 pm, ANS-6B The Black Aymara of the Bolivian Yungas. M.E. WARREN, epartment of Anthropology, University of Florida, Gainesville, 32611. In rural Bolivia oday there are hundreds of descendants of African slaves brought to work in the mines, omes, and coca plantations of Hispanic elites. They have been called "Black Aymara" ecause they have adopted many cultural and linguistic features of the Aymara peasants who are indigenous to the Andes. This paper presents the results of preliminary field work done in the summer of 1990 and library research on the Afro-Bolivians of the ungas.

:15 pm, ANS-7B Ethnicity and Stereotyping: The Views of Indian and White outh African Women About Each Other and About Blacks. BRIAN M. DU TOIT, epartment of Anthropology, University of Florida, Gainesville, Florida, 32611. It can onfidently be hypothesized that the greater a person's acquaintance and interaction with members of an ethnic group, the less likely are the chances of stereotyping. Conversel social distance, formal interaction, and threatening behavior produce negative image categorical thinking and generalizations represented in stereotyping. Interviewer aske women about their knowledge concerning and attitudes regarding other ethnic group Results confirm our expectations. As social boundaries are removed stereotypes ar broken down and prejudice fades.

3:30 pm, ANS–8B Women's Health and Reproductive Illness in the Caribbea A Reexamination of Explanatory Models. M.L. STAKER, Department of Anthropolog University of Florida, Gainesville, 32611. *Pedisyo* or 'perdition,' a reproductive illnes suffered by Haitian women, is an illness where women are pregnant for generally tw years or more. Recent attempts to understand this phenomenon have excluded biologic or psychological models in favor of sociological interpretations. The models develope have been based on the assumption that the illness is a phenomenon unique to Hai The recognition of a similar illness experienced by women in Para District, Surinam known as *winti-bere*, requires an expanded understanding of claims of unusually lor periods of pregnancy. A model is developed explaining the illness in the context gender relations indicating that this illness serves to increase the economic resourc available to women and stabilize relationships in cases where a woman is unable conceive.

3:45 pm, ANS–9B Dietary Taboos: The Convergence of Cognition, Gende Cultural Ecology, and Health Perspectives in a Brazilian Fishing Village. L.C. FORLIN Department of Anthropology, University of Florida, Gainesville, 32611. This pap examines dietary taboos as observed in the coastal fishing village of Arpoador, Maranha state, Brazil. The results of the study show that dietary proscriptions of fish relate to th community's concepts of health, gender and ecology. Three indigenous categories we elicited from informants regarding the edibility of fish: Manso (Mild), Reimoso (Unclear and Brabo (Harmful). Village members primarily mention health concerns whe proscribing the consumption of fish classified as reimoso. Women show a tendency observe dietary taboos more than men. These taboos also suggest a tacit conservatio ethic held by community members to spare fish from overpredation.

4:00 pm, ANS–10B Stress: Lessons from Rural Black Women with Diabetes. N. SCHOENBERG, Department of Anthropology, University of Florida, Gainesville, 3261 Medical, social science, and psychological researchers have recently written numero articles establishing that stress aggravates serious chronic diseases includir hypertension, diabetes, and gastrointestinal maladies. Despite many attempts to defin classify, discuss the etiology of, and treat stress, researchers have been unable to provi a discussion of stress that adequately and universally describes patients' experience Using open-ended questions within the context of a focus group, this study encourag Black rural women with diabetes to describe their definitions and perceptions of stress well as methods to alleviate stress. Although most of these women express simil causes of stress, their classification and strategies of managing stress is remarkab diverse. Since this group of culturally similar individuals display so much variatio recommendations designed to reduce stress in a more diverse population may ineffective. This study suggests that stress reduction measures may be most effective tailored to individual's observations, experiences, and needs.

4:15 pm, ANS-11B Diet and Compliance among Rural, African-American Women with Diabetes. L.S. LIEBERMAN (1), C.K. PROBART (2) AND N.E. SCHOENBERG (1), (1) Department of Anthropology (2) Department of Health Science Education, University of Florida, Gainesville, 32611. An intensive study of ten women with Type II Diabetes focused on home management strategies. A number of measures were used to assess food intake (24-hour dietary recall, food frequency questionnaire from the National Cancer Institute, and card sorts); and to assess attitudes, beliefs and knowledge about food (card sorts, interviews, focus groups). Data reveal a low-level of knowledge concerning food nutrients, recommended diets for people with diabetes. The participants expressed a number of reasons for the lack of compliance with recommended diets or what they thought were dietary recommendations. This paper will discuss dietary compliance in light of food knowledge and beliefs and life style factors that affect maintenance and change n food-related behaviors. This research was supported by the Diabetes Research and Education Foundation and a graduate research assistantship from the University of Florida.

:30 pm, BREAK

:45 pm
RESENTATION OF SECTION AWARDS

BIOLOGICAL SCIENCES

riday, 9:00 am – 11:45 am, Lewis Hall 205
ESSION A: Aquatic Biology
avid Bruzek, Florida Power Company, Presiding

:00 am, BIO-1A Inorganic Nitrogen Utilization Rates of Phytoplankton in Tampa ay. G.A. VARGO AND T. ORSOY. University of South Florida, Department of Marine cience, 140 - 7th Ave. S., St. Petersburg, FL 33701. The batch-perturbation method vas used to measure ammonium and nitrate utilization rates of Hillsborough Bay and ower Tampa Bay (Skyway) phytoplankton populations. Utilization (uptake + assimilation + growth) rates normalized to average chlorophyll concentration displayed maxima during pring and summer for both ammonium and nitrate particularly for the Skyway location. nnual integrated utilization rates were 1600 and 1800 uM for ammonium and nitrate in . Bay and 1225 and 1615 uM for ammonium and nitrate in H. Bay and 1225 and 1615 M for ammonium and nitrate at the Skyway. Nitrate input from various combinations of ver loadings, point and non-point sources and the standing stock could supply 5.8 to 6% of the measured N-use in H. Bay and 0.6 to 14.5% at the Skyway.

:15 am, BIO-2A Nitrogen Enrichment of Tampa Bay and Little Manatee River opulations. P. RODRIGUEZ AND G.A. VARGO, University of South Florida, Department f Marine Science, 140 - 7th Ave. S., St. Petersburg, FL 33701. Supported by SWIM. onthly samples from Tampa Bay and the Little Manatee River (12ppt salinity zone) were enriched with five Nitrogen (N) concentrations and with Silicate at two N levels. Fina yields were measured for 3 size fractions as Chlorophyll, Carbon and Nitrogen. The tota size fraction displayed positive, linear relationships ($r' > 0.9$) with the added N. Averag annual yields of N were equal for both locations although higher initial biomass wa present in the river. The >12 um size fraction dominated biomass in the bay with equa representation by smaller size fractions in the river prior to N addition. After N additions increases on the yield of the <12 and 5 um size fractions were minimal for both season and stations. Diatoms dominated and there was no indication of Si limitation. THes results indicate a long-term limitation of growth and biomass by N.

9:30 am, BIO–3A A New Species of Anorthoneis (Bacillariophyceae) Reporte from Rivers in Northern Florida. MICHAEL KENNETH HEIN, Water and Air Research, Inc 6821 S.W. Archer Rd., Gainesville, 32608. A new species belonging to the genu Anorthoneis is described from material collected from two rivers in Northern Florida. Th species is characterized by a valve length of 14-17 um; coarse, radial striae (19-21 per 1 um) on both valves; an eccentric raphe on the raphe valve (RV) and eccentric axial are on the rapheless valve (RLV); large central nodule on the RV; and a bilaterally dissimila central area which is unilaterally expanded on the wider side of the valve into an irregula to acute-angled sub-fascia on both valves. This is the first report of a freshwater specie of Anorthoneis.

9:45 am, BIO–4A Evidence of Algal Succession Due to Seasonality in Tw Brazilian Lakes. CARLOS A. FERNANDES AND THOMAS L. CRISMAN, Environment Engineering Science, University of Florida, Gainesville 32608. Lagoa Bonita and Lago do Parque Nacional are examined during one year period for their phytoplankto community and correlated environmental factors. The phytoplankton community appear quite similar in the two lakes; Dinophyceae and Chlorophyceae are dominant during a the year, despite the presence of Chrysophyceae. We also discuss the possible reason for the Bacillariophyceae presence only in Lagoa Bonita. The Dinophyceae an Chlorophyceae had showed an inversal successional pattern in the two environment suggesting competition, or just a community change due to the dry-wet season difference. The two studied environments are tropical oligotrophics Brazilian lake although Lagoa Bonita had displayed higher variations in the community's response du to the seasonality differences in the Cerrado region, suggesting highest eutrophic leve or a more disturbed environment.

10:00 am, BIO–5A Interaction of the Dinoflagellate, *Gymnodinium breve* with Othe Marine Algae. P.A. HASBROUCK, M.S. HENRY, AND R.H. PIERCE, Mote Marin Laboratory, 1600 Thompson Parkway, Sarasota, FL 34236. The interaction of the re tide organism, *Gymnodinium breve*, with other members of the marine phytoplankto community is of ecological importance for understanding red tide bloom dynamics. Th effect of algal growth was determined by monitoring cell populations of the red tic organism and other test algae in mixed (test) and unialgal (control) cultures over perioc of 5 and 14 days. In addition, the effect on red tide toxin production was determine The growth of marine algae (*Chlorella autotrophica* 580, *Nannochloropsis salir* GBSTICHO, and *Nannochloris* sp.) was inhibited when maintained in cultures with *G* *breve*. The red tide dinoflagellate appeared unaffected by the presence of other alga generating toxin and cell concentrations comparable to control values. The dinoflagellate's inhibitory properties may allow it to gain and maintain control of available nutrients within open waters thus enhancing the red tide bloom.

10:15 am, BREAK

10:30 am, BIO-6A Further Progress in the Purification of the Mate Recognition Pheromone from the Rotifer *Brachionus plicatilis*. K.S. VARGA, P.D. MORRIS, AND T.W. SNELL, Department of Biology, University of Tampa, 33606. Mate recognition in the rotifer *Brachionus plicatilis* is mediated by cell surface glycoproteins. These glycoproteins were extracted using EGTA then purified using lectin affinity chromatography. Electrophoretic separation of glycoproteins on 12% SDS gels, followed by silver staining, revealed ten protein bands with molecular weights from 11-62 kilodaltons. Glycoproteins were radioactively labeled with tritiated glucosamine and electrophoresed. An autoradiogram revealed four bands with molecular weights of 56, 37, 28, and 13 kilodaltons. Bioassays with the extracted glycoproteins and glycl-leucine covalently linked to sepharose beads elicited 26 male contacts, whereas beads treated with glycl-leucine alone elicited only 5 contacts. These findings indicate that the purification techniques used isolated a smaller number of glycoproteins which can account for mate recognition in rotifers.

10:45 am, BIO-7A Comparative Grazing Effects of *Chydorus sphaericus* on Blue Green Algae and Attached Bacteria. V. NILAKANTAN AND T.L. CRISMAN. Department of Environmental Engineering, University of Florida, Gainesville, FL 32611. Bacterial attachment of three species of blue green algae is studied using the electron microscope. Comparative grazing of *Chydorus sphaericus* on three species of blue green algae, *Microcystis* sp., *Lyngbya* sp. and *Anabaena* sp., attached bacteria and the free bacterioplankton in the water column is also studied, using radioisotope techniques. The methods used and results determined are described. It is estimated that *Chydorus* is more efficient at grazing the bacteria that are attached to algae than the free bacterioplankton. The cladoceran does not have any direct effect on the algae due to its nability to utilize them. The preferential grazing of *Chydorus* on bacteria may significantly enhance the algal populations due to clumsy feeding of the cladoceran and the release of extracellular material from the algae and bacteria.

11:00 am, BIO-8A A Comparison of the Infaunal and Epifaunal Macroinvertebrate Communities of the Pithlachascotee River in West-Central Florida. M.R. MILLIGAN AND A.P. McALLISTER, Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota, FL 34236. Macroinvertebrate communities were monitored quarterly during 1990 at two sites n the freshwater region of the Pithlachascotee River in Pasco County. Infauna was collected by diver core. Colonization of ariticial substrates was analyzed for two and four-week incubation periods. A total of 160 taxa was identified. The infaunal communities were dominated by chironomids with respect to both species richness and abundance. Each station was characterized by a unique combination of dominant taxa. The taxa comprising in excess of 1% of the epifaunal communities were the same at each site. Eleven of the twelve dominant taxa were chironomids. The diversity values of the epifauna exhibited distinctly different trends between the two and four-week incubation periods. Based on a comparison of the infaunal and epifaunal communities, substrate was considered to be the overriding factor for macroinvertebrate distribution.

11:15 am, BIO-9A Potential Impact of Freshwater Withdrawal on th Macroinvertebrate Community in the Upper Myakka River. A.P. McALLISTER AND M.R MILLIGAN, Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota, FL 34236. Th Myakka River Basin is a unique watershed in southwest Florida due to the unaltere nature of its undeveloped shoreline. Plans to divert freshwater from the river as a sourc of potable water have been proposed. This study was conducted to assess the potentia impact of that diversion. Infaunal and epifaunal macroinvertebrates were monitore quarterly from April 1989 to February 1990 along 7 transects from Down's Dam (RM26 to Snook Haven (RM18). Over 200 taxa were identified during this study. Each transec was dominated by a unique combination of clams, worms and insect larvae. Fauna densities decreased from April through September, subsequently increasing to February The benthic community throughout the study area was homogeneous for each samplin period, but variations in community composition and abundance were evident betwee collections. Freshwater withdrawal may allow for an increased movement for th saltwedge upstream, consequently affecting the distribution of euryhaline and stenotopi freshwater invertebrates.

11:30 am, BIO-10A Environmental Factors Affecting Densities of the Troglobiti Crayfish *Procambarus pallidus*. W.J. STREEVER AND M.G. WHEATLY, Department o Zoology, University of Florida, 420 Bartram Hall, Gainesville, FL 32611. *Procambaru pallidus*, an endangered troglobitic crayfish, inhabits fully-flooded cave systems in Florid Animal densities vary from cave to cave, and at different locations within individual cave An attempt was made to link *P. pallidus* densities to dissolved oxygen, organic conte of the substrate, and ion content of the water at seven sites within the Peacock Spring cave system in Luraville, Florida. In addition, the aquatic cave ecosystem is described i general terms. (Funded by NSF grant 89-16412).

11:45 am
BUSINESS MEETING: BIOLOGICAL SCIENCES
David Bruzek, Presiding

Friday, 9:00 am - 11:45 am, Lewis Hall 207
SESSION B
Betsy Davis, HDR Engineering, Presiding

9:00 am, BIO-11B An investigation of *Quercus Virginiana* and *Q. laurifol* (Fagaceae). D.E. WEDGE, Department of Biological Sciences, Florida Atlantic Universit Boca Raton 33431. Because of confusion in the horticultural trade between *Q. virginia* Miller and *Q. laurifolia* Michaux, an analysis of the traits that may be used to distinguis these two species was performed. Nineteen morphological traits of leaves and fruits we compared and evaluated with the computer program PAUP. The results of this comput analysis support the classical separation of these two named entities into distinct specie

9:15 am, BIO-12B Analysis of *Cenchrus incertus* Complex (Poaceae) Southeastern Florida. J.R. HICKLIN, Department of Biological Sciences, Florida Atlan University, Boca Raton 33431. Specimens in southeastern Florida have been identifie by various people as *C. incertus* M.A. Curtis, *C. tribuloides* L., and *C. paucifloru* Bentham. Morphological and ecological characters were taken from living and herberiu specimens. These traits were analyzed with the computer program PAUP. Data from DeLisle's 1963 revision were re-analyzed with this program. Results show that C. incertus and C. tribuloides are distinct species that are probably hybridizing. The taxonomic rank of C. pauciflorus is unresolved.

9:30 am, BIO-13B Pinus dolichophyllus (Nov. Sp.): Giving A Valid Name to Micheaux's P. australes (nomen. illig.). R.F. MENTE, Consultant, 939 45th St. N., St. Petersburg, FL. A medium-sized Diploxylon pine (Subsect. Australes), with long needles, up to 50.1 cm. length; while needles/fascicle in 2's & 3's, 3's, 3's & 4's and 2's, 3's & 4's. Oblong seed cones are very long, 18.0-21.0 cm., and their closed cone L/W ratio varies from 2.60-3.05; statistically well above that defined for P. palustris Miller, 2.00 max.. Dorsal umbo very broad and well armed. Bark is grey and in strips. Pinus dolichophyllus (Nov. Sp.) differre ab Pinus palustris Miller in acus numerare; semen conus longinquitas, longinquitas/latitudo de densus conus et optime armatus umbos.

9:45 am, BIO-14B A Report On Two New Statistically Based Varieties of Pinus dolichophyllus Mente. R.F. MENTE, Consultant, 939 45th St. N., St. Petersburg, FL. Based on repeated, extensive sampling, two new varieties of P. dolichophyllus Mente are proposed because they are statistically deviant from the norm of the species. In P. dolichophyllus v. quadrifolia (Nov. Var.) 20% of the needles/fascicle occur in 4's. Not only is the 20% discrete from the norm of 4's (c. 1.5%), using the Chi-Square Statistic, the chance occurrence of such a percent away from the norm is greater than 1 in 100 ($p>.01$). In P. dolichophyllus v. macrostrobus (Nov. Var.) the length of a population of seed cones (L:23.6 cm.) differs significantly, by Analysis of Variance from seed cones normal for the species. P. dolichophyllus v. quadrifolia (Nov. Var.) viginti portio acus in quattuor. P. dolichophyllus v. macrostrobus (Nov. Var.) civium semen conus mathematicus longinquitas ad "Analysis of Variance" ab semen conus aequabilis ad species.

10:00 am, BIO-15B Pinus X sondereggeri Chapman (Nov. Comb.): A description of Both Hybrid Forms Along With A New Hybrid Classification System. R.F. MENTE, Consultant, 939 45th St. N., St. Petersburg, FL. Field observations have led to the conclusion that tree form (crown) of a Pinus hybrid, has the same form as the species from which the pollen came, if correctly interpreted, then tree form is a sex-linked gene to the pollen (male) cone. Saylor and Koenig (1966) alluded to this observation, but never stated it, when describing hybrids of P. clausa (Englm.) Vasey and P. elliottii Englm.. Chapman defined P. X sondereggeri as a hybrid of P. palustris Miller and P. taeda L. and has mixed characteristics of both. Needles arise in P. palustris (alpha)-form and the P. taeda (beta)-form. Pinus X sondereggeri Chapman vertex forma P. palustris (alpha) Miller et vertex forma P. taeda (beta) L..

10:30 am, BIO-16B Two New Varieties of Pinus X sondereggeri (Chapman) Mente. R.F. MENTE, Consultant, 939 45th St. N., St. Petersburg, FL. In P. X sondereggeri alpha v. calverensis (alpha: P. palustris Miller form) (Nov. Var.) seed cones differ significantly, by Analysis of Variance, from P. X sondereggeri beta in length, length/width ratio, needles/fascicle do not occur in 5's and seed wings are striped, seeds are oval vs. obovate and are larger. In Pinus X sondereggeri beta v. polyphylla (beta: P. taeda L. form) (Nov. Var.) 29.9% of the needles/fascicle occur other than in 3's. This percent is not only discrete, but with the use of the Chi-Square Statistic its probability of occurrenc is less than 1 in 100 (p .01). P. X sondereggeri alpha v. calverensis (Nov. Var.) acus no in quinque, semen ovatus, semen ala linea et civium semen conus mathematicu longinquitas et long./latitudo aequabilis ad species. P. X sondereggeri beta v. polyphyllu (Nov. Var.) c. triginta portio acus in duo, quattuor et quinque.

10:45 am, BIO-17B Pinus Garrelsensis (Nov. Sp.): A Possible Mutated (? Diploxylon Pine (Subsect. Australes) from Clearwater, Fl. R.F. MENTE, Consultant, 93 45th St. N., St. Petersburg, FL. This medium-sized pine has needles/fascicle in 2's, 3's 4's, 5's and 6's that arise in spires. This species shares characteristics with three othe Diploxylon pines: the stalked (like P. elliottii Englm.), sub-terminal (like P. palustris Miller oblong seed cones sometimes occur in whorls 90° apart. The long seed cones (18.1 11.0 cm.) have reduced umbos and closed cone L/W population ratios of c.2.30 Measure dimensions of the grey bark and the needle lengths are similar to both palustris Miller and P. dolichophyllus Mente, whereas the needle sheath length (3.0-1. cm.) is close to the latter species. Pinus Garrelsensis (Nov. Sp.) differre ab Pinus palustri Miller ad acus numerare in duo, tres, quattuor, quinque et sex.

11:00 am, BIO-18B Pinus Charlierensis (Nov. Sp.) and Pinus St. Petersburgii (Nov Sp.): Two Diploxylon (Subsect. Australes) Pines From Pinellas Co., FL. R.F. MENTE Consultant, 939 45th St. N., St. Petersburg, FL. Pinus Charlierensis has a red bar demarcated into plates by black-dark grey fissures. The pollen cones ar characteristically persistent and the P. clausa (Englm.) Vasey-like cones commonly hav deciduous scales. The crown is full with a rounded to flat top. Pinus St. Petersburg (Nov. Sp.) has needles arising in brushes in 2's and 3's. The red platy bark is P. taeda like, but is smaller. Medium-sized cones usually have rounded bases like P. densa (L. D.) DeLaub. and Silba. Needle sheaths are more in the range of P. elliottii Englm.. Th tall tree has a P. taeda L.-like crown. P. Charlierensis (Nov. Sp.) differre ab P. claus (Englm.) Vasey rubere cortex et plene teres vertex. P. St. Petersburgii differre ab P. taed L. acus numere in duo et tres et parvus semen conus cum plus solito teres basis.

11:30 am, BIO-19B Pinus pinellasensis (Nov. Sp.) Beckner ex. Mente: Demarcated Red Barked Diployxlon Pine. Subsect. Australes. R.F. MENTE, Consultan 939 45th St. N., St. Petersburg, FL. This red barked pine has its plates deeply divided b black-dark grey fissures; it turns pale grey below 6°C. Needles arise in spires and occu in 2's and 3's. Excessive watering causes the green needles to turn yellow-gree Needles and their sheaths are generally longer than those of Pinus elliottii Englm however, the seed wings are not striped. Seed cones are statistically smaller by Analysi of Variance from those of Pinus elliottii Englm.. John Beckner and this autho independently arrived at the conclusion that this was a distinct species; albeit fro descriptive vs. statistical methods. Pinus pinellasensis (Nov. Sp.) differre ab Pinus elliot Englm. rubere cortex circumscribere ad ater-fuscus canus rima. Cortex flexus canus infr c.6°C. Semen conus mathematicus parvulus et semen ala non linea.

11:30 am, BIO-20B A Report of Over 50 Mutations/Morphological Changes An Their Consequences Observed on Pinue Are Inferred A Direct Result Of Global Warmin and Natural Radiation Damage (Ozone Depletion) In The Southeastern U.S.. R.F. MENTE

Consultant, 939 45th St. N., St. Petersburg, FL. There is direct evidence of low, medium and high level natural radiation damage, due to ozone depletion, as observed on primary shoots, needles, pollen cones and seed cones on Pinus sp.. Global warming is interpreted from preotinous (early flowering) pollen and seed cones. Witherspoon and Taylor's (1969) report on non-apical dominance was first observed in the field on pollen cones in 1989, although the data supports the conclusion that it probably was initiated in 1985. Non-apical dominance of primary shoots was noted in the field in Jan. 1991. Envaginated needle surfaces were observed from needles deciduous in Dec. 1990. Percent multiple-tipped pollen cones were the same from south FL to Anniston, AL over to SC in June 1990.

11:45 am
BUSINESS MEETING: BIOLOGICAL SCIENCES
David Bruzek, Presiding

Friday, 3:00 pm – 5:00 pm, Lewis Hall 205
SESSION C
Andy Squires, King Engineering, Assoc., Presiding

3:00 pm, BIO-21C The Implementation Of An Integrated, Interdisciplinary, Field-Oriented, Laboratory Curriculum In Biology. WILLIAM TRANTHAM, Florida Keys Community College, 5901 West Junior College Road, Key West, FL 33040. This project utilized a team teaching approach to train community college students in the application of scientific and technical equipment in the areas of astronomy, oceanography, ornithology, ecology and marine archaeology. This unique educational project utilized the MV Yankee Freedom as a laboratory platform to provide educators with a hands-on approach to the marine environment. The project focused on the oceanic island chain and hermatypic reefs from Key West to the Dry Tortugas.

3:15 pm, BIO-22C Image Analysis as a Tool for Environmental Studies of Seagrasses and Benthic Habitats. J.K. CULTER AND G. BLANCHARD, Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota, Florida 34236. Digital image analysis software (Bioscan OPTIMAS and Microsoft Windows) was utilized as a technical aid for two environmental studies. The system was utilized to process large numbers of seagrass samples for a thermal impact study on grass beds located near the Anclote River. The system provided data on blade length, total blade area, and average width for collections of turtle grass, *Thalassia testudinum* (Hydrocharitacea). An OPTIMAS program was developed enabling technicians without advanced computer skills to conduct rapid analysis of numerous replicates containing multiple blades. The system was also utilized for a study of Sarasota Bay bottom habitat. For this study, image analysis was used to calculate coverage of various types of benthic habitats discerned by inspection of aerial photographs and field investigations of Sarasota Bay. Quality assurance techniques of image calibration to ensure precision and repeatability were developed.

3:30 pm, BIO-23C A Comparison of Plotless Transects vs. Linear Percentage Sampling for Evaluating Stony Coral (Scleractinia and Milleporina) Diversity, Colony Density and Area Coverage on Reefs of the Exuma Cays Land and Sea Park, Bahamas.

M. CHIAPPONE AND K.M. SULLIVAN, Department of Biology, University of Miami, P.O Box 249118, Coral Gables, Florida 33124. Three methods of evaluating stony cora communities were used on selected reefs in the Exuma Cays Land and Sea Parl (24°22'N, 77°30'W) in the central Bahamas: species presence/absence, linear percentag and plotless transects. Shallow reefs (<4 meters depth) were selected from aerial survey based on size, location and physical setting, and grouped into three community types 1) channel patch reefs, 2) soft-coral sponge patch reefs and 3) fringing reefs. Dat collected from these survey methods was used to calculate coral colony density, specie area coverage, and species diversity based on colony number and linear coral cover.

3:45 pm, BIO-24C Trends of Water Quality and Biological Indicators in Tamp Bay, Florida. J.O.R. JOHANSSON, City of Tampa, Bay Study Group, 2700 Maritime Blvd. Tampa, FL 33605. Water quality in Tampa Bay has improved during the last ten years Improvements have been particularly noticeable in Hillsborough Bay, the subsection c Tampa Bay which historically has had the poorest water quality. Signs of bette conditions in this part of the bay are evident by increased water clarity and decrease chlorophyll concentrations. Improvements of these parameters appear related to a larg biomass reductions of a planktonic blue-green alga. Coincidental with improved wate quality, seagrasses and an attached macro-alga have vegetated shallow areas around th bay, which had been barren of attached vegetation for several decades. Th improvements in Hillsborough Bay appear related to a substantial reduction in externa nitrogen loading caused foremost by the conversion in 1979 of the City of Tampa' wastewater treatment plan at Hookers Point from primary to advanced wastewate treatment, and also by reduced discharges during the last decade of nitrogen fror fertilizer industry activities.

4:00 pm, BIO-25C The Status of Halodule wrightii in Hillsborough Bay, Florid W.M. AVERY, City of Tampa, Bay Study Group, 2700 Maritime Blvd., Tampa 33605. 1986 survey of Hillsborough Bay, by the City of Tampa, Bay Study Group (BSG), locate 137 patches of Halodule wrightii with a total coverage of 0.2ha. A subsequent survey i 1989 located 395 patches of H. wrightii and areal coverage had increased to 0.5ha. I 1987, the BSG transplanted about 13m² of H. wrightii to Hillsborough Bay. One area wa planted using bare root units and seven areas were planted with sod units using 2.5m of source material respectively. In fall 1990, bare root planting areal coverage ha increased to 290m² and areal coverage of the total sod unit plantings was approximatel 525m².

4:15 pm, BIO-26C The Seasonality and Abundance of the Tunicat Bostiobranchus digonas and its Relationship to Water Quality, in Hillsborough Bay Florida. E.V. PINSON, City of Tampa, Bay Study Group, 2700 Maritime Blvd., Tamp 33605. ph. 813-247-3451. Three stations, covering sediment types from mud to san have been sampled monthly since 1987 using a Standard Ekman dredge. Water qualit parameters have been measured with tunicate collections. Surface and botto chlorophyll-a measurements have been taken since January 1989. High filtration rates common in solitary asidians, coupled with large tunicate concentrations appears to lowe Chl-a concentration and produce good water quality in the vicinity of these communities

4:30 pm, BIO-27C The Environmental Impact of Cultured Hard Clams, Mercenaria mercenaria, Grown on the Bottom in Mesh Bags. R. MOJICA (1) AND W.G. NELSON (2), (1) Department of Biological Science, (2) Department of Oceanography and Ocean Engineering, Florida Institute of Technology, 150 W. University Blvd., Melbourne 32901. With 41 active hard clam growout operations, Florida is one of the top producers of cultured clams, yet little effort has gone into the study of possible impacts of such operations. To investigate these potential impacts, a 16-acre facility located on the Indian River Lagoon was compared with two adjacent control sites. Initial results indicate that while water quality varied little between the clam farm and control sites, higher levels of volatile organics were found in clam farm sediments. Some differential use of the clam farm was identified for mobile macrofauna while differences in benthic communities were less clear. Possible explanations for these results are examined.

4:45 pm, BIO-28C Diet and foraging patterns of Stingrays (Family Dasyatidae) in tropical, shallow-water marine environments. D.S.GILLIAM (1) AND K.M. SULLIVAN (2). (1) Nova University Oceanographic Center, 8000 N. Ocean Dr., Dania, FL 33004 and (2) Department of Biology, University of Miami, P.O. Box 249118, Coral Gables, Florida 33124. Stingrays (Family Dasyatidae) were observed, then collected in the Exuma Cays Land and Sea park (24°22'N, 77°30'W) in the central Bahamas. The diet of stingrays was investigated through stomach content analysis. The contribution of different prey items to the rays' diet was determined using indices based on numerical, volumetric and gravimetric importance, and frequency of occurrence of the individual items. Habitat preference were determined by comparing the preferred food items in the stomachs with benthic surveys and visual observations. Foraging patterns were based on visual observations of active rays and the state of digestion of stomach contents taken over time of day and tidal cycles.

Friday, 3:00 pm – 5:00 pm, Lewis Hall 207
SESSION D
Michael Hein, Air and Water Research, Inc., Presiding

3:00 pm, BIO-29C Home Range Estimates and Habitat Use Of Eastern Indigo Snakes On John F. Kennedy Space Center, Florida. M.J. KEHL, R.B. SMITH AND D.R. BREININGER, The Bionetics Corporation, Mail Code Bio-2, Kennedy Space Center 32899. Nine adult Eastern Indigo Snakes (*Drymarchon corais couperi*) were implanted with radio transmitters, released, and tracked beginning in January 1989. Each snake was located 2-3 times/week for periods ranging from 2-18 months. Locations were marked on aerial photographs. Habitat characteristics, time of day, and weather were recorded for each tracking event. GIS was used to plot locations for each snake and determine home ranges based on a convex polygon. Average home range estimates were 279.4 ha for males and 99.8 ha for females. Seasonal activity patterns, movements, den sites, and habitat use will be discussed.

3:15 pm, BIO-30D Gopher Tortoise Burrow Width to Body Size Relations. D.S. WILSON, H.R. MUSHINSKY AND E.D. MCCOY, Department of Biology, University of South Florida, Tampa 33620. Knowing the relationship between the width of a tortoise burrow and the carapace length of the resident individual facilitates demographic studies based on burrow width measurements. All burrows in seven central Florida populations were located and the width of each was measured at a depth of 50 cm. We captured a total of 79 individuals by trapping burrows judged to be active or inactive. We measured individual carapace length for comparison with burrow width. We computed a least squares regression equation to describe the relationship between burrow width and tortoise carapace length. We discuss our findings relative to those of others and offer an explanation for the strong relationship between burrow width and carapace length.

3:30 pm, BIO-31D Loggerhead Turtle Nesting Data from a Five Year Tagging Program on Casey and Manasota Keys. J.J. FOOTE (1), V.L. WIESE (1), T.L. EAST (1), J.F. SPRINKEL (1) AND J.F. McCARTHY (2), (1) Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota, FL 34236, (2) Sarasota County Department of Natural Resources, P.O. Box 8, Sarasota, FL 34230. From 1986 to 1990, 915 observances on 606 individually tagged loggerhead sea turtles (*Caretta caretta*) were made on Casey and Manasota Keys. Data obtained from each observance included information on nesting effort, straight line carapace lengths and widths, clutch size, hatching success, and, where appropriate, interesting intervals and nest site fidelity. No relationship was observed between carapace size and either clutch size or hatching success. The minimum nesting interval within any one season averaged 11.37 +/- 1.34 days (n=116). The longest nesting by individua turtles occurred 56 times in the same zone (each zone equals approximately 1 km o beach), 61 times in an adjacent zone, and 116 times in more distant zones. Taggec turtles were observed to nest from one to six times within a season.

3:45 pm, BIO-32D Movement Patterns and Habitat Utilization of the Easterr Woodrat (*Neotoma floridana floridana*) in North Central Florida. LESLIE HAYSMITH Department of Wildlife and Range Sciences, University of Florida, Gainesville, FL 32611 The natural history of the Eastern Woodrat, little understood in peninsular Florida, is examined from a behavioral-ecological perspective. Population dynamics of woodrats or the Ordway-Swisher Preserve, Putnam County are described. An analysis of home range size and pattern in mesic hardwood hammocks and bottomland hardwood swamp is presented. Habitat utilization of these forest types is analyzed through radiotelemetry Declining densities and external population pressures are briefly examined.

4:00 pm, BIO-33D Comparative Arboreality of Small Rodents in Florida. W.C PACKER (1) AND J.N. LAYNE (2), (1) University of Western Australia, Nedlands, Australia (2) Archbold Biological Station, Lake Placid 33852. Competition among small rodents occurring in the same habitat may be reduced through differential use of three dimensional space. We evaluated arboreal tendencies of the species that dominate Florida small mammal communities: *Podomys floridanus*, *Peromyscus gossypinus*, *P polionotus*, *Ochrotomys nuttalli*, *Sigmodon hispidus*. Three methods were used: (1 placing baits containing color-coded plastic particles on the ground and >1 m above ground and recovering the markers in feces of live trapped animals, (2) tendency o different species to climb or run off on the ground when released from live traps, and (3 numbers of acorns transported to elevated vs. ground level nest boxes in a laborator test. Species ranked about the same in relative arboreality on the three measures, anc interspecific differences in arboreal tendency generally agreed with predictions based or morphology, behavior, and ecology.

4:15 pm, BIO-34D The Hydroecology of Deer Prairie Slough: A Drainage Impacted Wetland. CHRISTOPHER SHEA, KEVEN ROHRER, AND KIMBERLY BABBITT, Sarasota County Ecological Monitoring Division, 1301 Cattlemen Road, Sarasota 34232. Deer Prairie Slough is a shallow, herbaceous slough draining the eastern half of the T. Mabry Carlton Jr. Memorial Reserve, a wellfield in central Sarasota County. The lower 2/3 of the slough was ditched in the 1940's. Monitoring of hydrology, vegetation and rainfall in Deer Prairie Slough began in 1985. The ditched lower section of the slough has a lower average water depth and shorter hydroperiod. Aerial infrared photography is useful in delineating areas of encroachment by wax myrtle (Myrica cerifera) and other woody upland species. The appearance of drought-adapted annual species, such as Sesbania macrocarpa, is more closely related to short-term rainfall deficit, as occurred in 1990. Drainage and drought impacts are compared and contrasted.

4:30 pm, BIO-35D Quantitative Sampling for Aquatic Plants and Fish, and Preliminary Data from Restoration Wetlands. J. DOUGLAS OLIVER, ANDREW J. LESLIE, AND WILLIAM M. BARTODZIEJ, Bureau of Aquatic Plant Management, Florida Department Natural Resources, Tallahassee 32399. Environmental studies of restoration wetlands often have been lacking in statistical rigor. We argue for more research studies to include quantitative estimates of macrobiota per unit area of wetland. A suggested method for such work is provided, a m^2 portable sampling methodology that already has been published as part of Okefenokee Swamp research. In newer research, we are successfully using the sampler to obtain densities of aquatic plants and fishes in herbaceous wetlands at Florida phosphate mines. Sites include several-month old planted unmucked and planted mucked mine restoration sites. Preliminary results for small marsh fishes suggest high numbers at the mucked restoration site, and lower numbers of fishes at the unmucked site.

4:45 pm, BIO-36D Wildlife Utilization of Small Isolated Wetlands in Central Florida. PATRICIA DOORIS (1), GEORGE ELIASON (1), GEORGE DOORIS (2), AND PATRICIA FESMIRE (3). (1) HDR Engineering, Inc. 5100 W. Kennedy Blvd. Tampa, 33609; (2) Saint Leo College, Saint Leo, Florida 33574; and (3) West Coast Regional Water Supply Authority, 2535 Landmark Dr., Suite 211, Clearwater, 33519. Wildlife observations were made in twenty-seven wetlands in Pasco County having areas of less than 5 acres. Information collected since 1986 on wildlife species occurrence and frequency was correlated to selected wetland vegetational and physical parameters in each of the observation wetlands. Parameters included wetland area, edge length, habitat type, degree of disturbance, and hydroperiod. Results indicated that the small wetland systems studies provided essential habitat for nesting, foraging, resting, and travel for a wide variety of species, including large mammals.

Friday, 4:30 pm - 6:00 pm, First Floor Hall, Lewis Hall
POSTER SESSION

BIO-P1 Studies on the Mangroves of Boca Ciega Bay, Pinellas County, Florida. I. A Field Experiment on the Decomposition of Rhizophora mangle, Avicennia germinans, and Laguncularia racemosa Leaves. PROFFITT, C.E., COCHRANE, C.B., JEPPESEN, S., JOHNS, K., LINDEN, D., PAYNE, D., PEEL, D., AND T.A. REYNOLDS. St. Petersburg Junior College, P.O. Box 13489, St. Petersburg, FL 33733.

BIO-P2 Studies on the Mangroves of Boca Ciega Bay, Pinellas County, Florida. II Survival and Growth of Rhizophora mangle Propagules of Varying Stages of Developmen and Levels of Herbivory. PROFFITT, C.E., CINQUINA, M.L., COCHRANE, C.B. FRASSETTO, K.A., GRAHAM, P.H., HORAN, D., JEPPESEN, S., MANTEAU, G.A., MOON J., PIACENZA, V., PUGH, T.E., AND D.P. WATTS. St. Petersburg Junior College, P.O Box 13489, St. Petersburg, FL 33733.

BIO-P3 Existing and Historical Vegetative Habitats of Lake Tarpon. A.P. SQUIRES AND D.E. ROBISON. King Engineering Associates, Inc., 24945 U.S. Highway 19 North Clearwater, FL 34623.

COMPUTER SCIENCE AND MATHEMATICS

Friday, 9:30 am – 11:30 am, Lewis Hall 307
Daryl Schrader, St. Petersburg Junior College, Presiding

9:30 am, CSM-1 The Use of Artifacts in Software Engineering Education, C.B ENGLE, JR., Florida Institute of Technology, Department of Computer Science, 150 W University Blvd., Melbourne 32901. Software Engineering is a subject with greater scop than computer science in that it is concerned with the entire life-cycle for the creation c a software system. In a one semester course, or even a two semester course, th effective use of the controlling disciplines of large-scale software development cannot b illustrated because the development cycle is too short. However, by providing large, wel documented artifacts for educators, the need for these controlling disciplines can b demonstrated. The documentation provided must be the full set of documents create during the development of the artifact. The controlling disciplines thus illustrated includ configuration management, verification and validation, and quality assurance. Othe benefits include the introduction to the student of a large (in academic terms) cod example and the management interactions between the controlling disciplines and th development team.

9:45 am, CSM-2 Building an Expert System for Design of Experiment ABOOTALEB VAFAIE-B, FREDERICK B. BUONI, and KAMEL REKAB, Department c Computer Science, Florida Institute of Technology, 150 West University Blvd., Melbourn FL 32901-6988. We describe the process of building a simple expert system to guide th experimenter to choose an appropriate design. We discuss a simple application fro semiconductor process design.

10:00 am, CSM-3 The Lovasz Basis Reduction Algorithm and the Subset Sum Problem: L. TADJ, Department of Computer Science, Florida Institute of Technology, 150 E. University Blvd., Melbourne, FL 32901. Various implementations of the Lovasz basis reduction algorithm are discussed, along with statistics on their performance. One of the implementations is then used in an attempt to solve the subset sum problem.

10:15 am, CSM-4 An Ada Prototype for an Intelligent Distributed Power Supply System for Space Applications. R. BAGGS AND R. MORRIS, Department of Computer Science, Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901. A prototype for a distributed power supply system which monitors, controls, and provides fault maintenance for space payloads will be discussed. Given the real-time environment and the necessity for reliability, the focus is on efficient reasoning methods which require little or no human intervention. The distributed nature of the solution will provide an alternative to centralized monitor and control which proves to be slow and fallible due to the repercussions should the central controller fail. The language Ada will be used in order to provide necessary concurrency and as support for object-oriented software design methods.

10:30 am, BREAK

10:45 am, CSM-5 CASE Tools Come of Age. O.M. MARPLE, Florida Institute of Technology, Department of Computer Science, Melbourne, FL 32901. The technology of Computer Aided Software Engineering is explored by first presenting elements typically found in CASE tools then discussing how these tools support the principles of software engineering.

11:00 am, CSM-6 A Teaching Tool for Linear Multi-Objective Programming. G. BOGER AND DR. FREDERICK B. BUONI, Department of Computer Science, Florida Institute of Technology, 150 West University Blvd., Melbourne, FL 32901-6988. We describe a program developed to teach linear multi-objective programming. The program uses subroutines from the XMP library and runs on a Macintosh computer.

11:15 am, CSM-7 Software Engineering as an Undergraduate Curriculum. L.S. CLEVER AND O.M. MARPLE, Florida Institute of Technology, Department of Computer Science, Melbourne, FL 32901. An approach to developing an undergraduate curriculum for software engineering is discussed. The differences between software engineering and computer science are noted as is justification for viewing this discipline as an emerging field of engineering. F.I.T.'s new undergraduate curriculum is described.

Friday, 11:30 am
SECTION MEETING: COMPUTER SCIENCE AND MATHEMATICS
Daryl Schrader, Presiding

ENGINEERING SCIENCES

Saturday, 10:15 am – 11:30 am, Lewis Hall 203
Betty Preece, Science Education Consultant, Presiding

10:15 am, ENG–1 Analysis of Thermal Stratification and Self Pressurization in Liquid Hydrogen Storage Systems. SEZGIN GURSU, Department of Mechanica Engineering, University of Miami, P.O. Box 248294, Coral Gables, Fl 33124. This paper reports on an optimization study to reduce boil-off losses in cryogenic hydrogen storage vessels. This includes an optimization of the initial para-hydrogen percentage, tank size, liquid level in the tank, number and locations of cooling stations, and tank pressure. This has been carried out employing a numerical model capable of calculating therma stratification and self pressurization effects for different ortho-para compositions.

10:30 am, ENG–2 Matrix Crack Extension in Fiber-Reinforced Brittle Matrix Composite. L. GU and P.L. MANGONON, Department of Mechanical and Aerospace Engineering, Florida Institute of Technology, Melbourne, FL 32901. Ceramic and intermetallic alloys are very attractive materials because of their high temperature and strength-to-weight ratio properties. Their usage is, however, hindered by their brittleness and low fracture toughness. One method to increase their fracture toughness is by fiber reinforcement, such as the case in reinforced concrete. This paper explores the influence of the fiber-reinforcements in the matrix crack extension as the fibers remain intact. A model is presented which is substantially different from earlier models to indicate a mechanical constraint or stress provided by the fibers as the crack opens up.

10:45 am, ENG–3 Analysis of Culvert Performance Utilizing a Spreadshee Program. C.E. KERSCHUS AND S.C. KRANC, University of South Florida, Tampa, 33620 The design procedure for culverts has been adapted to spreadsheet format to aid in making tedious and repetitive calculations. Furthermore, utilizing the enhanced capabilities of the design program, sensitivity of culvert performance to design parameters can be investigated. Typical results are examined and the problems with missing o unreliable data are examined. This work is supported in part by the Florida Departmen of Transportation/Federal Highway Administration. The opinions, findings an conclusions presented are not necessarily those of either agency.

11:00 am, ENG–4 Lead-210 and Cesium-137 Dating of Soft Lake Sediments Usin Low-Energy Gamma-Ray Spectroscopy. J.F. GOTTGENS, T.L. CRISMAN, AND W.E BOLCH, Department of Environmental Engineering Sciences, University of Florida Gainesville 32611. Direct gamma-ray spectroscopy was used to record changin concentrations of ^{210}Pb (unsupported and supported) and ^{137}Cs in sediment profiles from five locations in Newnans Lake (FL). This allowed reliable age/depth and dry-materia deposition rate calculations, in spite of potential sediment disturbances in this shallow lak with flocculent bottom deposits. Recent dry-sediment accumulation rates varied betwee 0.06 and 0.10 g cm^{-2} yr^{-1} and correlated with water depth (R^2=0.81, N=5). Depositio rates were not statistically different (alpha=0.05) from calculated values using an earlie independently developed model. Sediment profiles clearly reflect the impact of a 196 alteration in lake hydraulics. Benefits of gamma-ray spectroscopy include (1) simple nondestructive sample preparation, (2) simultaneous assay for other gamma-emitting radioisotopes including those of the ^{238}U series, which allows (3) direct estimation of changing levels of supported ^{210}Pb in the core profile. Its application to Florida's shallow, eutrophic systems provides a sedimentary record of past lake responses to perturbations. As such, changes to be expected following future lake management actions my be inferred.

11:15 am, ENG-5 Development of a Hybrid Rocket Engine Prototype. M.P. MOSES AND E.F. STROTHER, Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901. The design and development of a unique rocket engine prototype will be described. This engine, which has upper stage-exoatmospheric applications, such as orbital transfer, is a hybrid chemical-electrical device utilizing photoreactive propellants. Its operating characteristics and test results will be presented and discussed.

Friday, 11:30 am
SECTION MEETING: ENGINEERING
Betty Preece, Presiding

ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCE

Saturday, 9:00 am – 12:00 noon, Lewis Hall 303
Don Black, South Florida Water Management District, Presiding

9:00 am, ENV-1 Detection of a Hydroxamate Siderophore Produced by *Lyngbya majuscula*. ELSIE D. GROSS and DEAN F. MARTIN, Institute of Environmental Studies, Department of Chemistry, University of South Florida, Tampa 33620. *Lyngbya majuscula*, a common marine blue-green alga adapted to freshwater, showed significantly greater weight gain when grown in iron-sufficient media than *L. majuscula* grown in iron-deficient media. A similar demand for iron in many microbes induces the production of iron chelators known as siderophores. Siderophores of the hydroxamate class are known to be produced by at least two other cyanobacteria. A chloroform soluble extract from *L. majuscula* iron-deficient media gave a positive Csaky test indicating the presence of a bound hydroxamate thought to be a siderophore produced by *L. majuscula*.

9:15 am, ENV-2 The Effect of Toll Plaza Removal on Air Quality in Jacksonville, FL. R. DEL DELUMYEA AND JOHN T. BUTCHER, Millar Wilson Laboratory for Chemical Research, Jacksonville University, Jacksonville FL 32211. Air particulate samples were collected in 1989 for the three months prior to demolition of the Mathews Bridge toll plaza. The concentrations of total suspended particulate (TSP) matter and elemental carbon (EC) were determined and compared to values from four additional sites--industrial, residential, commercial, and rural. The same process was repeated one year later and the concentrations compared. Although a marked improvement in air quality at the former toll plaza site was documented, the concentration of particulate matter was not significantly reduced at the other sites.

9:30 am, ENV-3 Influence of Inorganics on the Determination of Elementa Carbon in Air Particulate Matter. JOHN T. BUTCHER AND R. DEL DELUMYEA, Milla Wilson Laboratory for Chemical Research, Jacksonville University, Jacksonville, FL 32211 Atmospheric particulate collection devices incorporate various inlet characteristics depending on the size of the particles to be sampled. Large particles contai considerable soil-derived matter with little combustion-derived elemental carbon (EC whereas the opposite is the case for small particles. The darkness of a filter containin particulate matter has been used to estimate the EC content; however, since the tota darkness of any sample is determined by the sum of all the colored components, th presence of metal oxides or other light-absorbing species would falsely elevate E concentration determined by an optical method. This paper discusses the relative effec of the presence of soil-derived particles on the elemental carbon content of sample collected using HiVol, Dichotomous, PM-10 and open-faced particulate collection devices

9:45 am, ENV-4 Implications of copper in the Florida environment. KERMI WEBB, BARBARA B. MARTIN, AND DEAN F. MARTIN. Institute of Environmental Studies Department of Chemistry, University of South Florida, Tampa 33620-5250. Since the earl 1900s, copper ion (in the form of copper sulfate, commonly) has been used extensivel as an algaecide to control nuisance algae in natural waters. As a consequence, there i concern over the fate and persistence of copper in the environment. We are concerne with potential removal of copper by naturally concurring chelating agents found in Florid rivers, and this paper describes our research efforts in this field.

10:00 am, ENV-5 Photoinitiated Autooxidation of Vegetable oil. E. OLSEN AN P. HAWTHORN. Science Department, Central Florida Community College, 3001 S College Blvd., Ocala 32678. The effect of various free radical scavengers on the rate oxidation of vegetable oil has been monitored by determination of the extent of peroxid development. Implications in the fields of agriculture and food processing are discusse

10:15 am, ENV-6 Synthesis of a Novel Bis (B-Diketone) as a Precourser for a Organometallic Diastereoisomer. N. VENKATRAJ, LEON MANDELL, AND DEAN MARTIN. Institute for Environmental Studies, Department of Chemistry, University South Florida, Tampa 33620-5250. 1,1,3,3-tetra(2-naphthoyl)propane was synthesized b aldol condensation followed by Michael addition in a single-flash synthesis. 1,3-di(naphthoyl)1,3-propanedione and aqueous formaldehyde in appropriate stoichiometry wer condensed in ethanol-toluene (83;17) in the presence of a piperidine catalyst. Anal. Cal for $C_{47}H_{32}O_4$: C,85.45;H,4.84%. Found: C,85.22;H,4.78%;M.p. 198°C (from 95% ethan 32% yield. This substance will be condensed with phenyl(p-tolyl)thalium(III)-chloride yield an organometallic compound that should exist as two sets of D,L isomers, and w plan to effect partial resolution over D-Lactose following procedures developed earlie The compound should also react with beryllium ion to form (1) a coordination polyme or (2) a dimer, or (3) a monomer. The monomer should exist as enantiomers, b resolution may not be feasible, based upon experience with a related bix (B-Diketone)

10:30 am, BREAK

10:45 am, ENV–7 Effects of Metabolic Products on Cellulose-Utilizing Organisms on *HYDRILLA VERTICILLATA* Royle. BRENDA L. POMPEY AND DEAN F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa 33620-5250. *Hydrilla verticillatta* Royle is a rootable submersed, perennial plant that reproduces by sexual or vegetative means. The plant was expelled into the canal in the last 1950's. By 1967, hydrilla was established throughout Florida and other southeastern states. Our interest has been the occurrence of natural products that appear to inhibit growth of hydrilla in lakes that have an organic sediment composed of peat-like detritus material from adjacent stands of cypress (Taxodium distichum). The research is focused on isolating organisms that utilize cellulose and produce metabolic products that inhibit the growth of hydrilla from sediments of lakes Starvation and White Trout. After ten days of growth, the filtrate was collected, sterilized, and a bioassy was run using hydrilla. The results indicate the presence of a growth inhibitor that will be studied and characterized further.

11:00 am, ENV–8 Removal of Cadmium from Industrial Phosphoric Acid Using Several Novel Chelating Agents. C.D. NORRIS AND D.F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa 33620-5250. Since the 1920's, cadmium has become recognized as a significant occupational disease problem. In Japan, Itai-Itai disease, a painful degenerative bone disorder, was attributed in 1946 to contamination of rice paddies by a nearby lead-zinc-cadmium mine. Phosphate rock contains 0.3 - 85 ppm cadmium depending on location; Florida phosphate contains about 10 ppm. A number of recently-developed chelating agents show potential to remove this cadmium from industrial phosphoric acid (approx. 44% H_3PO_4) prepared from phosphate rock. The sample is extracted, then analyzed by atomic absorption spectroscopy at 228.8 nm; the acid layer is analyzed before and after extraction for the presence of cadmium. By varying the chelate concentration and volume, the maximum load of cadmium for each agent can be determined, thus its efficiency as a cadmium extractor can be assessed.

11:15 am, ENV–9 Production of Nitrites/Nitrosoamines from Bis(ethanolamine)-copper(II)sulfate under Environmental Realistic Conditions. DEAN F. MARTIN, ROBERT S. BRAMAN, AND GLORIA J. FREDERICK. Institute for Environmental Studies, University of South Florida, Tampa 33620-5250. Significant amounts of chelated copper herbicides are used in Florida for treating aquatic plants. In the presence of high nitrite concentrations, relatively high (summer time) temperatures, and low pH, there is the possibility of the production of nitrosoamines, known carcinogens. Analysis for nitrite, nitrate, and nitrosoamine is carried out with aqueous solutions on a NO_x detector, which utilizes the reduction of these species to nitric oxide whose chemiluminescence is quantitatively observed.

1:30 am, ENV–10 Intrusion Indices - A Measure of Groundwater Quality. DEAN F. MARTIN, CHARLES D. NORRIS, AND BARBARA B. MARTIN, Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa 33620-5250. The ntrusion Index is the arithmetic mean of three indices--chloride, sulfate, and nitrate--that define the impact of human activities on groundwater quality in Florida and presumably elsewhere. The Intrusion Index and the component indices are arranged on a scale of

0-100 (0-59 is good, 60-69 is fair, and 70-100 is poor) in analogy with the Trophic Stat Index. The Chloride Index should reflect the impact of salt water intrusion. The Sulfat Index can reflect the impact of excessive pumping and contamination of the surficia aquifer by deep aquifer water, and the Nitrate Index can reflect the impact of agricultura activities, among others.

11:45 am, ENV–11 Dehalogenation of Trihalomethanes by a Nickel(II)-chelat Compound. PETER J. LUSCHINSKI AND DEAN F. MARTIN. Institute for Environment Studies, Department of Chemistry, University of South Florida, Tampa 33620-525 Previous studies have demonstrated that chloroform and other halogenated hydrocarbon can be dehalogenated by metal derivatives of N-butylsalicylaldimine. The present stud has demonstrated that the dehalogenation of trihalomethanes (chloroform an bromoform) can be achieved in aqueous solution using the nickel derivative and unde simpler conditions than hitherto used.

Friday, 12:00 noon
SECTION MEETING: ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCE
Don Black, Presiding

FLORIDA COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS

Friday, 3:00 pm – 4:45 pm, Lewis Hall 303
Ray Ashton, Water and Air Research, Inc., Presiding

3:00 pm, REB–1 Development and Implementation of a Computerized Sc Pattern Catalog for the Winter Population of the West Indian Manatee, *Trichechu manatus*, at Homosassa Springs, Florida. L.E. EVANS, JR. AND J.G. MORRIS, Biologic Sciences Department, Florida Institute of Technology, Melbourne, FL 32901. computerized manatee scar pattern catalog using Apple Hypercard software wa developed for the 1989 winter population of the West Indian Manatee, *Trichechu manatus*, at Homosassa Springs, Florida. This catalog consists of stacks of cards wi two data cards and several photo cards for each individual manatee. Black and whi 5 x 7 inch photographs of each individual's scar pattern were scanned into the comput and placed on one card for each photo. Data cards contain information such as se length, age class, location, status in population, sighting information, and identificati code. The identification code consists of the scar position codes, sex code, age clas code, and location code. The second data card also includes additional sighti information as well as a map showing sighting location.

3:15 pm, REB–2 Abundance and Distribution of the West Indian Manatee in th Grand Canal, Brevard County, Florida. K.A. HICKS, J.G. MORRIS, Biological Scienc

Department, Florida Institute of Technology, Melbourne, FL 32901. A survey of the Grand Canal was conducted from February through September, 1990 to determine the extent of utilization by the West Indian Manatee. Boat traffic was also examined to determine relationships between boat and manatee distribution. Two hundred and eighty-three sightings were recorded, consisting of a possible 245 individuals. The majority of sightings were of adult females. There were 28 sightings of cow/calf pairs. The distribution of manatee sightings among sections in the canal was significant for every month of the study except for February. There was a negative correlation between number of boats and number of manatees in secluded areas. The Grand Canal was determined to be a high density manatee area. Deep calm channels, fresh water sources, and low boat traffic are the attractive characteristics of the area for the manatee.

3:30 pm, REB–3 Florida Burrowing Owl (Athene cunicularia floridana) usage of Gopher Tortoise (Gopherus polyphenmus) burrows. R.E. ASHTON, JR. AND E.L. MOSURA, Water and Air Research, Inc., 6821 S.W. Archer Rd., Gainesville, FL 32608. Three surveys of owl burrows were conducted on a 1700-acre pasture site in Sumter County, Florida, from June, 1989 to November, 1990. Thirty-five active burrows being used by approximately 11 pairs of owls were located. Of these, 74% were found to be constructed by gopher tortoises of which 33% (N=13) showed signs current used by tortoises while 42% (N=16) were inactive tortoise burrows. Such use of tortoise burrows by burrowing owls has not been previously reported. Use patterns of these burrows such as dispersing offspring into surrounding burrows, shows some parallels, with behaviors displayed by western owls and their use of prairie dog burrows. An on-going, long-term monitoring study of this small owl population may further establish the importance of the commensal relationship between tortoise and owl.

3:45 pm, REB–4 Response of small mammals to a fire in a riverine marsh. J.M. BUHLER (1), AND I.J. STOUT (2), (1) PBS&J, 1560 Orange Ave., Winter Park, 32789, (2) Department of Biology, University of Central Florida, Orlando, 32825. An arson fire swept through approximately 460 acres of spartina marsh located within the Seminole Ranch Wildlife Management Area along the St. John's River. Two of 3 permanent trapping grids within the marsh were burned. The grids had been established in 1987 and 3 years of data on pre-burn conditions were available. Small mammals observed in the habitat ncluded the cotton rat (Sigmodon hispidus), rice rat (Oryzomys palustris), and cotton mouse (Peromyscus gossypinus). We documented the recovery of the small mammal community for 4 months following the fire event. Cotton rats reoccupied the burned areas within 4 weeks. Some former residents returned to the vicinity of pre-burn home ranges. Male cotton rats dominated among the animals live trapped. Cotton rats, rice rats and cotton mice were resident with 7 weeks post-burn.

4:00 pm, REB–5 Measurements and Body Mass of Resident and Wintering American Kestrels in Southcentral Florida. J.N. LAYNE AND D.R. SMITH, Archbold Biological Station, Lake Placid 33852. Body mass and selected linear measurements of esident (Falco sparverius paulus) and wintering (F. s. sparverius) American kestrels in southcentral Florida were compared for the purpose of developing better criteria to distinguish the two subspecies where they occur together in winter and to detect possible evidence of breeding between them. Male and female paulus were significantly ($P < 0.05$)

smaller than the respective sex of sparverius in mass and four of five linea measurements. The two subspecies were best separated by mass, with male and femal paulus being about 20% lighter than the corresponding sex of sparverius. Sexua dimorphism in size was slightly greater in sparverius than paulus. Coefficients of variatio of mass and measurements were closely similar in the two subspecies, suggesting a absence of hybridization.

4:15 pm, REB–6 Characterization of the Florida landscape and its significanc in the conservation of biodiversity. V.L. LARSON AND H.M. SWAIN, Department c Biological Sciences, Florida Institute of Technology, 150 W. University Blvd., Melbourne FL 32901. Conservation efforts have in the past been limited largely to the protection c pristine natural communities. Clearly, biodiversity will not be maintained in these protecte areas alone. Characterization of the landscape can provide information on the potentia role of rural land in the conservation of biodiversity. Acreage, composition, and positio of the components of the rural landscape are significant considerations when determinin an area's conservation value. The Indian River Lagoon Watershed, in east central Florid will be used to demonstrate the role of rural land in the conservation of biodiversity an specifically in the protection of natural communities and threatened and endangere species.

4:30 pm, REB–7 Rare Convolvulaceae in the southeastern United States. D.F AUSTIN, Department of Biological Sciences, Florida Atlantic University, Boca Raton 3343 A survey of the convolvulaceae in the southeastern United States shows that fourtee species are rare. A few of these are currently listed on some endangered lists, whil others are not. Range, floristic affinities, and endangerment is given for Bonami grandiflora, Calystegia catesbeiana, Calystegia soldanella, Evolvulus alsinoides, Evolvulu convolvuloides, Evolvulus grisebachii, Ipomoea macrorhiza, Ipomoea microdactyl Ipomoea tenuissima, Jacquemontia curtissii, Jacquemontia reclinata, Jacquemont havanensis, Stylisma abdita, and Stylisma aquatica.

FRIDAY, 4:45 pm
SECTION MEETING: FLORIDA COMMITTEE ON RARE AND ENDANGERE PLANTS AND ANIMALS
Ray Ashton, Presiding

GEOLOGY & HYDROLOGY

Friday, 8:00 am – 10:30 am, Lewis Hall 113
W.S. Burns, South Florida Water Management District, Presiding

8:00 am, GHY–1 Water Budget Analysis - Preliminary Results Volusia Floridan Sole-Source Aquifer. R.P. HAVILAND. MiniLab Instruments, 1035 Green Acres Circle, North, Daytona Beach, FL 32119. The concept of an aquifer water budget analysis program was described at the 1990 annual meeting of the Academny. The model considers rainfall, evaporation, transpiration, surface and internal layer vertical and horizontal flow, springs, leakage use. Calibration and interpretation of results for the Volusian aquifer system is proceeding. A first finding was that the pre-development potentiometric level was surprisingly insensitive to rainfall variation. Search for reasons for the post-1955 level decline led to modification of the program to include the effects of drainage canals. Preliminary results of the combination of use, drainage and rainfall variation are included. Future work includes better model calibration, reduction of node size, and investigation of effects of possible management techniques on general and local aquifer conditions.

8:15 am, GHY–2 Development Potential of the Floridan Aquifer in Southeastern Florida Using Reverse Osmosis Treatment. JONATHAN E. SHAW, P.G. (1), KEITH R. SMITH, P.G. (2), AND NANCY A. SAWKA (1). (1) Blasland, Bouck & Lee, 951 Broken Sound Parkway, N.W., #185, Boca Raton, FL 33487, (2) South Florida Water Management District, P.O. Box 24680, West Palm Beach, FL 33416. While the Floridan Aquifer acts as the principle source of drinking water in much of northern and central Florida, it has gone essentially untapped in the southern portion of the state. This results from the presence of the prolific Biscayne Aquifer, which has been able to sustain the burgeoning growth of south Florida. Excessive reliance on the Biscayne Aquifer, especially in the coastal regions, has led to incidences of salt water intrusion contaminating wellfields. Efforts to establish wellfields further inland are hampered by ground water with high trihalomethane formation potential. To meet increasingly stringent Federal drinking water standards, many utilities are conducting membrane treatment systems. The cost of these units has decreased significantly over the past 20 years and have many advantages over conventional lime softening treatment plants. Membrance treatment plants are suitable for treating the brackish ground water drawn from Floridan Aquifer wells. The use of the Floridan Aquifer as a major water source in south Florida would, 1) relieve stresses on the surface water conveyance system, 2) reverse the andward gradient of the salt water interface, 3) not be susceptible to drought, 4) eliminate he presence of trihalomethane precursors in the water supply, and 5) be free of contaminants migrating from the surface, thereby, eliminating the need for wellfield protection zones. As this trend to utilized the Floridan Aquifer increases, the South Florida Water Management District must identify the production potential of the aquifer to properly allocate the resource. An in-depth investigation of the hydrogeologic characteristics of he Floridan Aquifer in south Florida, the water quality and the engineering aspects of everse osmosis membrane treatment and brine disposal options, is being conducted. The results of the investigation will be depicted on maps identifying producing zones within the aquifer, the water quality and the proper membrane treatment system.

8:30 am, GHY–3 Solute Transport Modeling of Shallow Recharge in the Biscayn Aquifer, Hollywood, Florida. ERIC F. REGENSBURGER AND JONATHAN E. SHAW Blasland, Bouck & Lee, 951 Broken Sound Parkway, N.W., Suite 185, Boca Raton, F 33487. The City of Hollywood, Florida has increasing concerns regarding salt-wate intrusion to the Biscayne Aquifer water supply wellfield. Several eastern wells have bee taken out of service as a result of increased chloride concentration. The City i developing a plan to prevent further landward movement of the salt-water front whil simultaneously disposing a portion of the City's reclaimed water by injecting highl disinfected effluent into the Biscayne Aquifer along a line of wells approximately two mile west of the Atlantic Ocean. The project's purpose is two-fold: to meet the "Ant degradation" regulation which limits ocean outfall disposal and eventaully discharge 10 t 15 million gallons per day of reclaimed water and, to create a fresh water mound in th highly transmissive Biscayne Aquifer. The mound will increase seaward gradients in th fresh water, thus pushing the salt-water front seaward or at least stablizing it at its curren position. To anticipate the effects on the salt-water front from artificial recharge, the tw dimensional solute transport code, SUTRA, was implemented. To determine whic variables had the greatest effect on the salt-water front, a sensitivity analysis wa performed with the model. The following model variables were systematically altere during the analysis: injection depth; rate of recharge; number of recharge points; an distance of recharge from the ocean. The sensitivity analysis determined which variable have the greatest effect on the salt-water front. Results were used to determine th aquifer recharge scenario that most effectively controlled salt-water intrusion. The result should indicate how changes in water levels impact the salt-water front. In addition, th location of wells and injection zones must be chosen to have the greatest impact on th salt-water front such as in highly transmissive layers within the Biscayne Aquifer.

8:45 am, GHY–4 Lithofacies of the upper Pleistocene Miami Limestone of Sout Florida. RICHARD A. JOHNSON, Independent stratigrapher, P.G. #60, P.O. Box 356 Tallahassee 32315. The Miami Limestone is defined as all oolitic/pelletal lithologie physically continuous with the typical oolitic limestone of the Atlantic Coastal Ridge in th city of Miami, Dade County. As thus defined, the Miami consists of five distinct lithofacie which represent lithologic-continua end-members: ooid calcarenite; Cheilostom bryozoan, molluscan (*Donax* sp. or *Chione cancellate*), or foraminiferal (*Archaias* sp calcirudite; breccia; oomoldic recrystallized; and quartz sandstone. The Miami consis of typical ooid calcarenite in the Atlantic Coastal Ridge of southeastern Dade County, an in the Lower Keys of Monroe County. In northern and western Dade, southern an eastern Broward, southeastern Palm Beach, mainland Monroe and southeastern Colli Counties, the Miami consists predominantly of the four remaining lithofacies.

9:00 am, GHY–5 Coquinas Have Fossils Too: The Anastasia Formation Martin and Palm Beach Counties. DONALD W. LOVEJOY, Palm Beach Atlantic Colleg P.O. Box 3353, West Palm Beach 33402. The Anastasia fauna is of interest because litt attention is generally paid to the fossil contents of this rock type. Additionally, the fossi shed important light on the environment in which coquina is deposited. Eleven specie of mollusks are present, as well as occastional non-molluscan forms--including the bor shell of a sea turtle. Tubular structures are frequently seen in the outcrops and a attributed to two or more kinds of burrowing organisms. Because the shell fragments a so thoroughly worn and polished, it is assumed that the coquine accumulated in the high-energy environment of offshore bars or a beach. Supporting evidence is provided by the fact that only the thickest and sturdiest shell types are represented. However, the significance of the high degree of bioturbation is less clear.

9:15 am, BREAK

9:30 am, GHY-6 A Gamma Ray Profile Investigation of the Upper Pleistocene Miami Limestone of South Florida. RICHARD A. JOHNSON, Independent stratigrapher, Professional Geologist #60, P.O. Box 3560, Tallahassee, 32315-3560. The Miami Limestone of southeastern peninsular Florida consists of white to yellow to brown-yellow, oolitic or pelletal limestone. Nineteen hand-held scintillometer gamma ray profiles of the Miami are obtained from outcrops and a continuous core in Dade, Broward, Palm Beach and Monroe Counties. Four well-defined, alternating higher and lower intensity, gamma ray zones are detected, with a higher intensity of the Fort Thompson Formation (limestone). The uppermost-Miami consists of a low-intensity zone at or near land surface.

9:45 am, GHY-7 Saltwater Intrusion Monitoring in Broward County, Florida. ANNE M. MURRAY, P.G., James M. Montgomery, Consulting Engineers, Inc., 2328 10th Avenue North, Fifth Floor, Lake Worth, Florida 33461. Saltwater intrusion is a major concern for coastal utilities in Broward County, Florida. An analysis of existing saltwater ntrusion monitoring wells was conducted and recommendations made for an improved monitoring network to track saltwater movement. Data from over 400 chloride monitoring wells were examined, evaluated spatially with respect to wellfields, and for many wells, the data were examined for temporal trends. Based on this analysis, saltwater intrustion is a present threat to coastal wellfields and is effected by proximity to the ocean and canals, groundwater elevations, drainage activites, drought events, and local geology. Saltwater ntrusion monitoring can be improved by verifying existing monitoring well locations, construction and water quality profiles to provide an accurate database, constructing dditional wells, imposing chloride testing standards, creating a control board to oordinate and evaluate data collected from various entitles, and developing a saltwater ntrusion model for eastern Broward County.

0:00 am, GHY-8 Use of an Optimization Model to Determine Permittable Groundwater Withdrawals in Hendry County, Florida. KEITH R. SMITH, South Florida Water Management District, P.O. Box 24680, West Palm Beach, 33416-4680. Hendry County is experiencing a dramatic growth in citrus production. The accompanying heavy emand for irrigation water has placed the groundwater resources of the county under tress. A three-dimentional groundwater flow model was developed for the Hendry ounty area. Groundwater use projections were developed through the year 2010. The model, in conjunction with an optimzation module, was used to determine the optimal ates and locations of groundwater withdrawals for a variety of drought and water use rojectoins. The determination of optimized groundwater withdrawals were constrained y minimum water levels in aquifers, drawdown limitations, and impacts to wetlands. The esults of this effort will be incorporated into the Lower West Coast Water Supply Plan, hich will be used to guide the development and use of the water resources of the area.

10:15 am, GHY-9 A Preliminary Study of Stable Oxygen Isotope in Tampa Bay T. NETRATANAWONG, W. SACKETT, AND M. HOLMES. Marine Science Department University of South Florida, 140 7th Avenue South, St. Petersburg, 33701. Tampa Bay i an ideal place to investigate the hydrological cycle using stable oxygen isotope. The delt Oxygen-18 (vs SMOW) of aqueous samples vary depending upon water types, source and various reactions. In Tampa Bay estuary the del Oxygen-18 are -2.2 and + 1.3 0/0 for water at S = 2.0 and 30.0, respectively. A linear correlation between the salinity and de Oxygen-18 in the Tampa Bay has been found. For rain water and previous ground wate collection del Oxygen-18 values are about -3.0 o/oo. Tap water from Hillsborough an Pinellas counties have enriched in del Oxygen-18 (-2.5 to -2.0 o/oo) with respect t source ground water. These basic data of hydrological cycle will help further understna water budget and resources in the Tampa Bay and adjacent areas. Additionally, sa water intrusion on Floridan aquifer can be easily inferred. Brief discussion on involve chemical reactions will be presented.

10:45 am, GHY-10 Hydraulic Control Structures for Wet Detention Systems. K.C McCARTY AND S.C. KRANC, University of South Florida, Tampa, 33620. Hydrauli control structures such as weirs and orifices are often used in conjunction with we detention systems to regulate the outflow of stormwater. Proper design of thes structures ensures that flood attenuation, treatment of poor quality runoff and recharg can be accomplished. This investigation is concerned with improving design data for th control structures and examining the effects of skimmers and other factors that ma modify the flow. Performance characteristics of typical structures are presented an possible modifications to existing design data are discussed. This work is supported b the Florida Department of Transportation/Federal Highway Administration. The opinion findings and conclusions presented are not necessarily those of either agency.

Friday, 10:45 am
SECTION MEETING - GEOLOGY & HYDROLOGY
W.S. Burns, Presiding

MEDICAL SCIENCES

Saturday, 10:00 am - 11:00 am, Lewis Hall 207
Arvind Dhople, Florida Institute of Technology, Presiding

10:00 am, MED-1 Cross-reactivity of the Pollens of *Paspalum notatum* (Bahia *Callistemon citrinis* (Bottlebrush) and *Melaleuca leucadendron* (Melaleuca). S. HOSSEIN S. HUNTER, S.D. KLOTZ, R.S. WHITE AND M.J. SWEENEY. Department of Molecul Biology and Microbiology, University of Central Florida, Orlando 32816. A high degre of cross-reactivity among the pollens of bahia (BA), bottlebrush (BO) and melaleuca (MI have been observed in skin testing studies. Preliminary results obtained with 55 random selected patients demonstrated that 81% of patients with skin test positive to at least one of the three pollens were also positive to the other two. SDS-PAGE analysis showed that extracts of ME, BO and BA contain multiple components which react with all three rabbit antisera (anti-ME, anti-BO and anti-BA). Allergic sera tested and analyzed by Western blotting showed unique patient IgE binding patterns indicating heterogeneity of the immune response.

10:20 am, MED-2 Comparative Studies on Decontaminants Against M. gordonea. M. IBANEZ AND A.M. DHOPLE. Department of Biological Sciences, Florida Institute of Technology, Melbourne, FL 32901. Most clinical specimens to be examined for mycobacteria contain other microorganisms that can overgrow the slowly growing mycobacteria. Because of this, the isolation of mycobacteria depends on suppression of growth of contaminants. Various laboratories use different contaminating agents, thus obtaining varying results. In present studies, four decontaminants were used to study the effects on M. gordonea, both in pure cultures and also mixed with normal sputum specimens. The maximum recovery of M. gordonea was obtained with 10 minutes exposure with sodium hydroxide. Exposure for less than 10 minutes might improve the yield. Oxalic acid was the next choice. The worst agent was sodium hypochlorite. The results on the recovery of M. gordonea from sputum specimens will be presented.

10:40 am, MED-3 Isolation of Cultivable Mycobacteria from Feces and Lungs of Armadillos Infected with M. leprae. A.M. DHOPLE, L.C. LAMOUREUX, E.E. STORRS, S. WILLIAMS, AND A. MURPHY. Department of Biological Sciences, Florida Institute of Technology, Melbourne, FL 32901. M. avium-intracellulare (MAI) complex is frequently a cause of disseminated infection in patients with AIDS, and the isolation of MAI from stools of AIDS patients has been reported. Recently, we have isolated MAI from various organs of M. leprae-infected armadillos and lately, from large number of lung specimens from these animals. So, this study was undertaken to determine the relation, if any, in mycobacteria isolated from these lungs and those isolated from fecal samples of these armadillos. Seventy percent of armadillos infected with M. leprae showed systematic infection and among these 31 animals (50%), showed presence of cultivable mycobacteria in lungs and feces, but not in livers or spleens. On the other hand, 21 animals (33%) showed cultivable mycobacteria isolated from both feces and lungs, 50% were M. gordonae, 26% M. fortuitum and 12% each MAI and M. kansasii. The implications of these findings will be discussed.

SATURDAY, 11:00 am
SECTION MEETING: MEDICAL SCIENCES
Arvind Dhople, Presiding

PHYSICS AND SPACE SCIENCE

Friday, 3:00 pm –4:00 pm, Lewis Hall 203
Paul Simony, Jacksonville University, Presiding

3:00 pm, PSS-1 UBV Photometry of 27 Euterpre. J.A. SMITH (1), B.J. SMITH (2), AND T.D. OSWALT (1), Florida Institute of Technology, 150 West University Blvd. Melbourne 32901, (1) Department of Physics and Space Sciences, (2) Department o Applied Math. UBV photometry of the minor planet 27 Euterpe has been obtained as par of an ongoing program to examine stellar occultation targets. Euterpe has a reporte rotation period of 8.500 hours (Chang and Chang, 1962) and surface colors of (B-V)= +0.87 and (U-B)= +0.49 (Bowell, Gehrels and Zellner, 1979). Our results do not agre with these data. Instead, we find the rotation period to be either 9.111 or 8.097 hours an the average surface colors to be (B-V)= +0.87 and (U-B)= +0.39. A noticeable chang in the average color is observed with rotation, indicating that changes in composition ma occur across the surface.

3:15 pm, PSS–2 Sandpiles and Self-Organized Criticality. J.D. PATTERSON Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne 32901. Numerical experiments have been done on the cellular automata or "sandpiles introduced by Bak, Tang and Wiesenfeld. The occurrence of the self-organized critic state, in which avalanches of all sizes are generated, is spontaneous. The literatur already relates these processes to l/f noise, fractal structures, earthquakes, and magneti domain patterns.

3:30 pm, PSS–3 TS-24: Computer Simulation of a 24" Research Telescope C. YOUNG, Crystal Lake Observatory, 4585 Lake Waterford Way, #10, Melbourne Florida, 32901. TS-24 is a computer program for the IBM or Macintosh computer th simulates the actual use of a 24" research telescope. TS-24 is a low cost alternative t actual scientific instrumentation for use in training students the process of data collectio data analysis and interpretation of results. Students begin by searching for variable star using the telescope's digital CCD camera to photograph the night sky. Variable star found are then further analyzed using the telescope's UBV photometer to record the lig curve and spectral characteristics of the star over time. By comparing the collected dat with known variable stars, students are able to identify the type of variable star discovere and to predict its future behavior. TS-24 is currently being used by students in Brevar County secondary schools and colleges.

3:45 pm, PSS–4 Radiation Augmented Chemical Reactions in Space Propulsio E.F. STROTHER, Florida Institute of Technology, Department of Physics and Spac Sciences, Melbourne, FL 32901. A method of augmenting chemical reactions by exposin certain photosensitive molecules to electromagnetic radiation will be presente Specifically, molecular hydrogen which combines unspectacularly with gaseous molecul chlorine (Cl_2) will react explosively and hyperbolically in the presence of chlorine in excite atomic states (Cl^*) or ionized (Cl^-) states. This powerful exothermic reaction, which offe unique advantages as a candidate propellant system in advanced upper stage rock engine designs, will be discussed.

Friday, 4:00 pm
SECTION MEETING: PHYSICS AND SPACE SCIENCE
William McCord, Presiding

SCIENCE TEACHING

Friday, 9:00 am – 11:30 am, Selby Auditorium
SESSION A
John Rimsa, St. Petersburg Community College, Presiding

9:00 am, TCH–1A Science Summer Institutes for K-12 Teachers. ALEXANDER K. DICKISON, DAVID BARRIGER, LAWRENCE McADAM, JEANNE ROBINSON, SHELTON SPARKS, AND WALTER TRIBLEY, Seminole Community College, 100 Weldon Blvd., Sanford, 32773. During the summers of 1989 and 1990, Seminole Community College and the Seminole County Public Schools cooperated in sponsoring teacher institutes for K-12 teachers. Subject matter included: Astronomy, Biology, Chemistry, Environmental Science, Geology, and Physics. This paper will explain how this program was organized, funded, and staffed. Experiences and reactions of the involved teachers will be given.

9:40 am, TCH–2A A Discussion of the Different Methods of Rounding Used in ntroductory Science Courses. K.A. WINDMEIER, Science Department, Manatee Community College, 8000 So. Tamiami Trail, Venice 34293. Two different methods of ounding are discussed and the relative merits of each method are explored. Some of the disadvantages of the odd-even rule of rounding are considered. It is suggested that science instructors adopt a uniform method of rounding to avoid confusion among the students.

0:10 am, TCH–3A Flexibility, The Key To Survival For Developmental Education n The Chemistry Curriculum. J.P. RIMSA and M. ROBINSON, St. Petersburg Junior College, P.O. Box 13489, St. Petersburg, 33733. The open-door admissions policy at the St. Petersburg Junior College has resulted in a considerable number of students entering he chemistry program at S.P.J.C. without adequate preparation. Eighteen years ago the hemistry department instituted a self-paced, independent study, developmental chemistry ourse for the purpose of meeting the needs of inadequately prepared students. The ongevity of this self-paced, independent study chemistry course is attributed to the exibility which is incorporated into its design. This presentation will trace the evolution f the developmental chemistry program at S.P.J.C.

0:35 am, BREAK

1:00 am, TCH–4A The Implementation Of An Integrated, Interdisciplinary, Field-riented, Laboratory Curriculum In Environmental Marine Science. WILLIAM TRANTHAM, lorida Keys Community Colelge, 5901 West Junior College Road, Key West, FL 33040. his project utilized a team-teaching approach to train primary and secondary school ducators in the application of scientific and technical equipment in the areas of stronomy, oceanography, ornithology, ecology and marine archaeology. This unique ducational project utilized the MV Yankee Freedom and the SV Stars and Stripes as boratory platforms to provide educators with a hands-on approach to marine vironmental education. Communities studied in the project included the oceanic island ain and hermatypic reefs from Key West to the Dry Tortugas as well as the shallow water habitats of turtle grass and mangroves from East Harbor Key to Snipe Point in th Gulf of Mexico. Funding was provided under a title II-Education for Economic Securit Federal Grant.

FRIDAY, 11:30 am
SECTION MEETING: SCIENCE TEACHING
John Rimsa, Presiding

Friday, 3:15 pm – 5:00 pm
SESSION B
John Rimsa, Presiding

3:15 pm, TCH–5B Motivators and Innovators. These presentations will be five (minute topics by science faculty featuring their favorite demonstrations, student handout and other student aids which the presenter has found to stimulate student learning. A li of participants will be included as a program supplement which will be available at the tim of registration.

SOCIAL SCIENCE

Friday, 10:15 am – 11:15 am, Lewis Hall 119
Bob Shearer, Florida Institute of Technology, Presiding

10:15 am, SOC–1 Back to the source: Bartram, Coleridge and Hurston. PATTERSON, Humanities Department, Florida Institute of Technology, 150 W. Univers Blvd., Melbourne, 32901. Literary critics have recently concentrated on the way in whi one writer encloses another text in his or her work. The problem of intertextuality rais questions involving the genesis, development, and quality of a writer's or a text's influen on another. This paper investigates the connection between William Bartram seventeenth century narrative describing his journey through Florida and Samu Coleridge and Zora Neale Hurston. Bartram's influence on Coleridge has been lo recognized. Hurston identified Coleridge as one of the poets that influenced h development. What has remained largely ignored is the process in which Hurston dr either consciously or unconsciously on Bartram's descriptions of Florida.

10:30 am, SOC–2 Caliban's Curse: Shakespeare and Colonialism. RUDOL STOECKEL, Humanities Department, Florida Institute of Technology, 150 W. Univers Blvd., Melbourne, FL 32901. In Shakespeare's The Tempest, Caliban represented t "natural" man; rude, yet uncontaminated by courtly European political ambition. T paper examines Shakespeare's apparent ambivalence regarding the Europea enslavement of the unruly native.

10:45 am, SOC-3 Rewards, intrinsic motivation, and achievement motivation. M. RAICH, Charter Hospital, 4004 Riverside Dr., Tampa, 33603. One of the more surprising, yet stable findings reported over the last 20 years in studies on intrinsic motivation is that contingent rewards of all kinds seem to undermine it. Intrinsic motivation is often represented by the willingness of individuals to perform an interesting and challenging task when such rewards are absent. The major theory in the area suggests contingent ewards are controlling, or pressure behavior toward particular outcomes, while intrinsic motivation is maintained only when control is not salient. However, an examination of the iterature shows that contingent rewards do not always undermine intrinsic motivation. Its evel appears to be a function of the magnitude of the reward offer and the level of achievement required to earn it. The literature is discussed in this area, and a model of achievement motivation is presented that appears to account for the findings. Data supporting the model are provided.

1:00 am, SOC-4 Daniel Defoe and the English Encounter with Islam. N.K. MATAR. Humanities Department, Florida Institute of Technology, Melbourne, Florida 2901. The 17th century witnessed contacts with the Muslim world on various levels, military, commercial and religious. Daniel Defoe was the first novelist to address this ontact in his work, adumbrating thereby the colonial perception that would dominate uture English perception. The references to the Muslims are interspersed in Defoe's writings and portray the transformation from the 'neutral' to the 'orientalizing' position owards Islam.

riday, 11:15 am
ECTION MEETING: SOCIAL SCIENCE
ob Shearer, Presiding

AMERICAN ASSOCIATION OF PHYSICS TEACHERS

aturday, 7:30 am –9:30 am, Saint Leo Cafeteria

30 am, BREAKFAST, Saint Leo Cafeteria

30 am
USINESS MEETING
ll McCord, Presiding

15 am
eport of American Association of Physics Teachers, San Antonio Winter Meeting, Alex ckison, Florida Section Representative

turday, 9:30 am – 11:45 am, Selby Auditorium
SSION A
ul Simony, Jacksonville University, Presiding

9:30 am Second Annual Lowell Seacat Memorial Lecture
Women in Physics: Why So Few and What Can We Do About It?
Judy Franz, President, American Association of Physics Teachers
West Virginia University, Morgantown, WV 26505

10:25 am, BREAK

10:30 am, APT-1A Physics for Gifted Students: A Report of an Internationa Conference on Physics for Precollege Students. R.G. HIMES, Edgewater High Schoo 3100 Edgewater Drive, Orlando, 32804. A conference of teachers of talented physic students and international physics olympiad mentors was held in Hungary this past Jul (1990). Precollege and college physics teachers of Sweden, Belgium, Polan Czechoslovakia, Hungary, Italy, Cyprus, Thailand, Korea, Soviet Union and the Unite States gave insight into the pedagogy, problems and solutions of teaching physics to hig ability students. Teaching methods and educational organization of other countries w be described and information on the international physics olympiad will be provided.

11:00 am, APT-2A Misconceptions and Operation Physics, BETTY VAIL, We Orange High School, Winter Garden, 32787, JACK BRENNAN, Physics Departmen University of Central Florida, Orlando, 32816. Operation Physics is a national effort t increase the quality and quantity of physics taught in 4th-8th grades. One aspect is t point out to the 4th-8th grade teachers preconceptions - alternate conceptions misconceptions that students have prior to instruction. This paper will list some of th physics misconceptions that have been identified and discuss some of the strategies an techniques that can be used to deal with them in 4th-8th grade.

11:15 am, APT-3A Physics and the Philippines by JACK BRENNAN, Physic Department, University of Central Florida, Orlando 32816. This paper will discuss hig school and college physics instruction in the Philippines. It will discuss the attempts bei made to improve the science and engineering infrastructure which the leadership feels necessary for the Philippines to become a Newly Industrialized Country (NIC). The auth will note the changes he has seen between 1983 & 1990.

11:30 am, APT-4A A Nontraditional Approach to Teaching the Nonmajors Colleg Physics Course, K.A. WINDEIER, Science Department, Manatee Community College, 80 South Tamiami Trail, Venice 34293. Traditionally, the one-semester nonmajor's colleg physics course has been a watered-down version of the major's physics course. I w compare the results of teaching the "traditional" course in a community college to o which has a different emphasis. Some of the approaches to physics teaching adopt by the (now out-of-print) text Physics and Human Affairs, by Art Hobson, are included the latter course, along with additional changes and innovations. Discussion and alterna opinions will be welcomed.

12:00 noon, LUNCH, Saint Leo Cafeteria

Saturday, 1:00 pm - 2:30 pm, Selby Auditorium
SESSION B
Bill McCord, Valencia Community College, Presiding

1:00 pm, APT-5B The Introductory Physics Laboratory: Love It or Leave It? ROBERT G. CARSON, Physics Department, Rollins College, Winter Park, 32789. The laboratory component of introductory physics courses has been questioned as to its cost by administrators, its efficacy by teachers, and its enjoyability by students. What role should the laboratory play in this last decade of the twentieth century? I will address a number of issues including the use of "fun" labs, what to do about the infamous weekly lab report, the insertion of problem workshops, and ways to more fully integrate the laboratory with the theory. This latter topic has been developed more completely by Priscilla Laws, et. al. at Dickson College and called Workshop Physics. Comments on its scope will be offered.

1:15 pm, APT-6B Integrating PC's into an Existing Introductory Physics aboratory Course. P.R. SIMONY, Department of Physics, Jacksonville University, acksonville, FL 32211. The Introductory Physics Laboratories at Jacksonville University re being revised to include use of microcomputers primarily for analysis and presentation f data. Rationale for the revisions will be presented. Hardware and the choice of oftware will be discussed in terms of utility, cost and compatibility with existing apparatus.

:30 pm, APT-7B Final Report on an Undergraduate Electro-Optics Laboratory, .S. BROWDER, P.R. SIMONY, Department of Physics, Jacksonville University, acksonville, FL 32211. At the previous Florida AAPT meeting we reported on our initial xperiences with our new electro-optics laboratory course. Based on our experiences ith the lab the last two years, revisions have been made in the course. A report on ese revisions and an evaluation of the effectiveness of the lab will be given, as well as uggestions for further improvements.

:45 pm, APT-8B A Summer AP Physics Workshop. ALEXANDER K. DICKISON), JAMES HELMICK (2), AND NELSON H. McAFEE (3), (1) Seminole Community ollege, 100 Weldon Blvd., Sanford, 32773, (2) Lake Brantley High School, Altamonte prings, 32714, (3) Countryside High School, Clearwater, 34621. A five-day summer orkshop of AP Physics was held. Twenty teachers from around the state attended. The achers in attendance had varied backgrounds, from active involvement in teaching AP ysics, to serious consideration about teaching it, to merely curiosity about what the ourse involves. The workshop was divided between problem solving and developing emonstrations/experiments. All the participants left with a notebook of worked problems d a box of materials and equipment. The energy and enthusiasm at the workshop was ry evident. Highlights of the past workshops and plans for next summer's workshop ll be given.

0 pm, ATP-9B Operation Physics: An Awakening to Science in Cooperative aching and Integrated Learning. DAWN R. ADAMS AND BILL HAMILTON, Mt. Dora hristian Home and Bible School, Mt. Dora 32757. Results of the use of Operation ysics for teacher-training for grades K-12 is discussed. Student and teacher attitude anges toward physics are examined, and the implementation of a cooperative teaching ogram using the secondary physics teacher and K-6 teachers is discussed. A video of elementary level physics lesson using cooperative teaching is shown. Samples of dents' work are shown that demonstrate integration of physics into the other ciplines.

2:15 pm, ATP-10B National Interactive Media: Videodiscs with Oldies but Goodie from the 60's and 70's. JIM NELSON (1), AND JANE BRAY NELSON (2), (1) Harrito High School, 600 N. Ithan Ave., Rosemont, PA 19010, (2) University High School, 1150 Eastwood Dr., Orlando. The purpose of this presentation is to introduce a new series videodiscs being developed and produced by AAPT under an NSF Grant. They are collection of out of print video materials such as PSSC films, Project Physics films, Ealir Ripple Tank Series, etc. They cover topics such as modern physics, E & M, mechanic conservation principle, waves, and heat. Participants will be able to see how these disc allow students to take data from actual footage. They are good for college labs or to he high school teachers meet the Florida State lab hours requirement.

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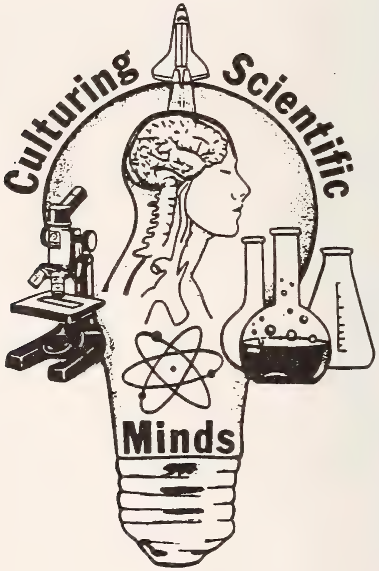
1991 ANNUAL CONVENTION



October 17-19, 1991
West Palm Beach, Florida

Host Hotel:
Royce Hotel
1601 Belvedere Road
West Palm Beach, FL 33406
(407) 689-6400

Site of Sessions:
Santaluces High School
6880 Lawrence Road
Lantana, FL 33462

FOR MORE INFORMATION CONTACT:
Corinne Measelle, Convention Co-chairperson
School Board of Palm Beach County
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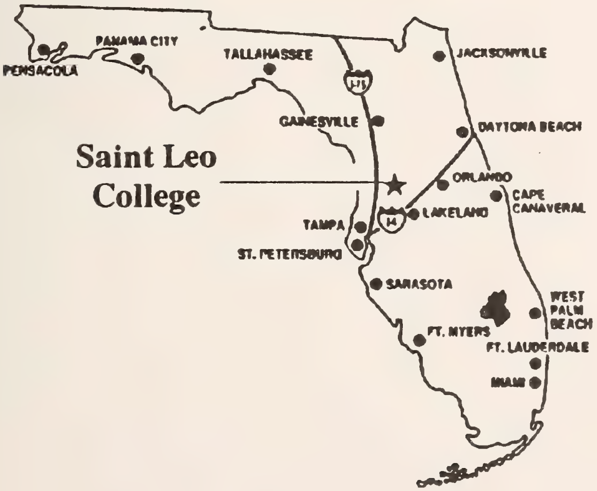
The Florida Endowment for the Sciences was established by the Florida Academy of Sciences in 1986 to receive exceptional gifts and hold and invest such funds for the long-term support of the purposes of the Academy. At present, all funds received in payment of dues by Patron and Life Members are placed in the Endowment, which is administered by three Trustees nominated by the Executive Committee and appointed by the Council.

Contributions to the Florida Endowment for the Sciences are a meaningful way to express your support for leadership in scientific research and education in and for Florida. Please consider a donation to the Florida Endowment for the Sciences when you renew your Academy membership or evaluate your annual tax status. Within limits of federal and state law, all donations to the Endowment are tax-exempt.

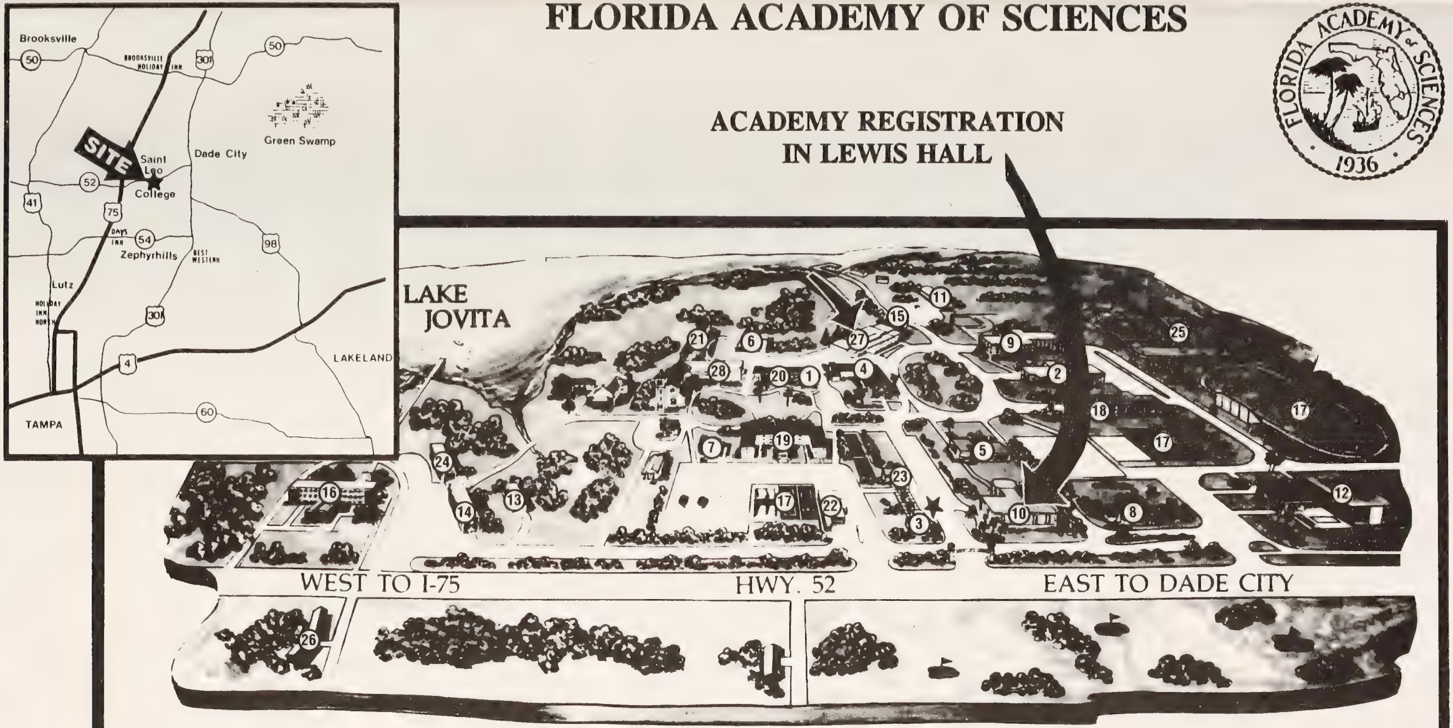


LOCATION OF THE 1992 ANNUAL MEETING

The Academy is pleased to announce that the 1992 annual meeting will be held March 12-14 at the Valencia Junior College, Orlando, Florida.

FLORIDA ACADEMY OF SCIENCES

ACADEMY REGISTRATION
IN LEWIS HALL



1 Admissions—Saint Francis Hall
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4 College Theatre
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6 Daniel A. Cannon Memorial Library
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9 Henderson Hall
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THE 56th ANNUAL MEETING

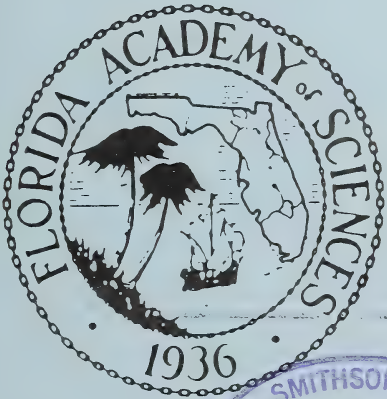
FLORIDA ACADEMY OF SCIENCES

MARCH 12-14, 1992

VALENCIA COMMUNITY COLLEGE
Orlando, Florida

Florida Scientist

IN TOUCH
WITH PEOPLE



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Program Issue

Volume 55

Supplement 1

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THE 56th ANNUAL MEETING

FLORIDA ACADEMY OF SCIENCES

March 12-14, 1992
Valencia Community College
Orlando, Florida

held in conjunction with the

Florida Junior Academy of Sciences
and the
Florida Section of the
American Association of Physics Teachers

PLENARY SESSION (Panel Discussion):
"Environmental Education PDQ: Progress, Direction, Query"

BANQUET ADDRESS:
"The Importance of Oceans on the Greenhouse Effect"

Dr. Frank Millero
Rosensteil Marine Laboratory
University of Florida

FLORIDA SCIENTIST
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1992 Florida Academy of Sciences 56th Annual Meeting

WELCOME

George Dooris, 1991-92 President

Welcome to the 56th Annual Meeting of the Florida Academy of Sciences. The Florida Academy is the only organization in Florida that represents all branches of Science. The Academy publishes a well-respected journal, the Florida Scientist, and supports the activities of future scientists through the Junior Academy of Sciences. Our Annual Meeting gives members the opportunity to present papers, honor their peers and participate in multi-disciplinary scientific exchanges. Join with us in what I trust you will find to be a most enjoyable and intellectually stimulating meeting.

MEETING INFORMATION

GENERAL INFORMATION ON MEETING

Information about the meeting program and the Florida Academy of Sciences may be obtained from the Executive Secretary, Mrs. Betty Preece, P.O. Box 033012, Indialantic, FL 32903-0012, phone (407) 723-6835.

LOCATION

Valencia Community College is located in the heart of Central Florida and serves the residents of Orange and Osceola counties, one of the fastest growing regions in the country.

Since its establishment in 1967, this multi-campus comprehensive community college has grown to be the fourth largest of Florida's 28 community colleges which make up the strongest community college system in the nation.

The West Campus at 1800 South Kirkman Road is a beautiful 180 acre campus with a sparkling lake and state-of-the-art physical facilities. The college is governed by a District Board of Trustees.

REGISTRATION

All participants are expected to register. A registration desk will be open in the lobby (Room 100) of MODULE 1 from 7:30 am to 4:00 pm on Friday March 13 and from 8:00 am to 9:30 am on Saturday March 14. The registration fee is $15.00 for FAS members, $20.00 for nonmembers, and $5.00 for students. Members receive the program issue by mail, as will others registered by February 1, 1992. Extra programs cost $4.00.

LODGING

No reservations can be made through the Academy. There are numerous hotels near the West Campus. Most of the major hotel chains have locations on or near the International

Drive area. The following hotels may give discounted rates if Valencia Community College is mentioned at the time reservations are made. Most require a credit card number or one night prepayment for reservations.

COMFORT INN: 5828 International Drive, Orlando, FL. (407:351-4100).
Daily rate (mention VCC) for one person: $45.00; two persons: $60.00.

COMFORT INN: 3956 W. Colonial Drive, Orlando, FL. (407:291-1200).
Daily rate (ask for VCC Corporate Rate) for one person: $45.00; two persons: $56.00; suite: $60.00.

DAY'S INN: 7200 International Drive, Orlando FL. (407:351-1200)
Daily rate (Mention VCC and ask for Jane) for one-four persons: $45.00.

LAS PALMAS INN/BEST WESTERN: 6233 International Drive, Orlando FL
(407:351-3900). Daily rate (ask for VCC Corporate Rate) for one person: $50.00.

MARIOTT INN: 6700 Sand Lake Road (corner of International Drive), Orlando FL. (407:351-2420) Daily Rate (ask for VCC Corporate Rate) for one person: $110.00; two persons: $120.00.

RAMADA RESORT: 7400 International Drive, Orlando FL. (407:351-4600). Daily rate (ask for VCC Corporate Rate) for one or two persons: $76.50.

TWIN TOWERS: 5780 Major Blvd., Orlando FL. (407:351-1000)
VCC Corporate Rate: $65.00.

MEALS

The college cafeteria, in MODULE 2, will be open on Friday and Saturday, for breakfast (7:00-8:30 AM) and lunch (12:00-1:00 PM).

BANQUET

The Academy Social and Banquet will be held on Friday evening, March 13, 1992 at the cafeteria in Building 2 on the west campus of Valencia Community College. The Academy Social will begin at 6:30 PM and the Banquet will begin at 7:15 PM. Dinner will be buffet style and will consist of an entre selection of either Chicken Cordon Bleu or Eggplant Parmesan, plus a tossed salad with dressing, vegetables, potato, rice or pasta, assorted desserts and beverages. Cost will be $15.00 including gratuity. The meal will be followed by the Medalist Program and the Awards Ceremony. Participants should preregister for the banquet, since only a limited number of tickets will be available at registration.

COUNCIL MEETING

The Executive Committee and Academy Council will meet at 1:00 pm on Thursday March 12, 1991, in Room 1-154.

ANNUAL BUSINESS MEETING

The Academy's annual business meeting will begin at 1:15 pm in Room 1-154. Members of the Executive Committee and Chairs of sections and standing committees are asked to bring written 1991-1992 reports.

PLENARY SESSION

A panel discussion will be the feature of the Plenary Session, which begins 1:30 pm on Friday, March 13, 1992. The panel will discuss actions, directions and resources in environmental education. Interaction time will be provided with speakers who are providers of, or activists in, environmental education in Florida.

Panel moderator: R.A. Karpie, Brevard Community College.

Panel members are:

Dr. David LaHart, Director, East Central Florida Regional Service Project
David Brown, National Estuary Project
Dr. Joseph Siny, Rollins College

and tentatively,

Dr. Kathleen Shea Abrams, Director, Environmental Education, Florida Department of Education
Jack Leppert, Chief Technical Assistant, Division of Community Colleges and Office of Environmental Education, Florida Department of Education

INFORMATION FOR SPEAKERS

All rooms have slide projectors and screens. Speakers wishing to use transparencies (overhead slides) should verify with their session chair that one will be provided for that session. Speakers requiring special equipment must contact the chair of the local arrangements committee. Student speakers should identify themselves to the session chair prior to speaking.

If an author or co-author is scheduled to speak but cannot attend due to unforseen circumstances, arrangements should be made for a colleague to present the paper. If a reader cannot be found, the paper should be cancelled. The Academy must be notified of a substitute speaker or cancellation by contacting the appropriate section chair.

ANNOUNCEMENTS

Local Arrangements. Meeting arrangements at Valencia Community College are co-ordinated by William McCord, chair of the Local Arrangements Committee, who may be consulted on any aspect of meeting support, including special services, by calling (407) 299-5000, ext 1441.

Publication. The 1992 Annual Program Issue is Supplement Number 1 to Volume 55 of the Florida Scientist and will be distributed to more than 200 domestic and foreign libraries as well as major abstracting services.

"Space Challenges: Earth and Beyond", the 1992 National Convention and Student Conference of the Society of Women Engineers, will be held June 22-28, 1992, in Orlando, Florida. For registration or other information, contact Michele Mingoia at (407) 869-2020 (work) or (407) 876-4758 (home); or Lisa Bird at (407) 383-2200 (work) or (407) 366-1574 (home).

Moving Sale. Relocation of the Academy office makes it possible to offer the following sets of The Florida Scientist at the registration desk of the 1992 Annual Meeting (all issues perfect):

5 sets: 1970-1990, inclusive-less six issues
  Regularly $272; Sale $150 per set
3 sets: 1970-1980, inclusive, complete
  Regularly $116; Sale $75 per set
1 set: FAS Symposium Proceedings (collection of 8 issues)
  Regularly $63.50; Sale $50
10 sets: Estuary Research and Management (set of 3 issues)
  Regularly $23; Sale $15 per set
Annual sets for many years after 1970 are available at $6 per set, a savings of 40%.
A limited number of complete sets (since 1936) at $500 each.

Florida Junior Academy of Sciences Meeting. The annual meeting of the Junior Academy will be held March 12-13, 1991 at Valencia Community College. Volunteers are needed to assist in the Judging of Student Papers on March 13. Section Chairs are expected to act as judges. Other persons interested in participating should contact the FJAS Coordinator: Mrs. Dorothy Henley, 4520 NE 15th Terrace, Ft. Lauderdale FL 33334 (tel. 305-491-2900).

Special Activities for Junior and Senior Academies. A partial list of activities planned to date is given below:

THURSDAY, March 12

- 6:30-9:30 PM. Judging for the Junior Academy of Sciences will be performed. Section Chairs and Chairs-Elect should participate in both activities.

FRIDAY, March 13

- 8:00-9:00 AM. Breakfast for Junior and Senior Academies. FAS Section Chairs and members will meet informally with FJAS members.

- 9:00-10:00 AM. "How to Do Science on the Florida School Budget". Panel of JAS Sponsoring Teachers and FAS members will discuss how to cope with the Florida education budget cuts. Participants are solicited from the JAS. The FAS Science Teaching Section will take part.

- 10:00-10:30 AM. **Special Presentation For FJAS and FAS** "Voyage to the Planets" by FAS Councillor Prof. Daryl L. Schrader, Professor of Astronomy and Mathematics, St. Petersburg Junior College and adjunct Astronomer, University of South Florida. An interesting pictorial visit beyond the Earth.

FCREPA Business Lunch. The Florida Committee on Rare and Endangered Plants and Animals will hold its annual business meeting during the Friday noon hour (11:30 AM-1:10 PM) in the buffet room of MODULE 2. The agenda for the meeting includes the election of a Chair-elect, and a report on the progress made on the new FCREPA Endangered and Threatened Biota series. Everyone is welcome.

The Third Annual Lowell Seacat Memorial Lecture, sponsored by the Association of Physics Teachers, will be held at 10:00 am Saturday, March, 14, 1992 in room 1-154.

FIELD TRIP TO BULL CREEK WILDLIFE MANAGEMENT AREA. The field trip is planned for SATURDAY, March 14 from approximately 9 AM to 2 PM. Approximately 35 persons can be accommodated but volunteers with access to 4-wheel drive vehicles are needed. Indicate interest on Registration Form and contact Robin Huck for details at (904) 461-2000. Bull Creek Watershed, an area of 10,522 ha., is in east-central Florida, on the eastern edge of Osceola County, 30 miles west of Melbourne and 35 miles west of the Atlantic Ocean. Most of the watershed is owned by the State of Florida.

PROGRAM SUMMARY

THURSDAY AFTERNOON, MARCH 12, 1992

1:00	FAS Council Meeting	1-154

THURSDAY EVENING, MARCH 12, 1992

6:30	FJAS Judging	1-154

FRIDAY MORNING, MARCH 13, 1992

7:30	Registration (to 4:00 pm)	1-100
8:00	Breakfast, Junior/Senior FAS	MOD-2
8:15	Agricultural Science, Session A	1-148
9:00	Anthropology, Session A	1-149
	Environmental Chemistry and Chemical Science *	1-229
	Rare and Endangered Biota, Session A *	1-230
10:00	Agricultural Science, Session B *	1-148
	Urban and Regional Planning *	1-251
10:15	Social Sciences *	1-129
10:30	Anthropology, Session B	1-149
	Biological Science, Session A *	1-154
	Biological Science, Session B *	1-152

FRIDAY AFTERNOON, MAY 13, 1992

1:15	Academy Meeting	4-120
1:30	Plenary Address I	4-120
3:00	Anthropology, Session C *	1-149
	Rare and Endangered Biota, Session B	1-230
	Biological Science, Session C	1-154
	Biological Science, Session D	1-152
	Biological Science, Poster Session	1-100
	Geology and Hydrology *	1-148
	Physics and Space Science *	1-251

FRIDAY EVENING, MAY 13, 1992

6:30	Academy Social Hour	MOD-2
7:30	Banquet	MOD-2
8:30	Plenary Address II	MOD-2

SATURDAY MORNING, MAY 14, 1992

8:00	AAPT Breakfast	MOD-2
9:00	AAPT Business Meeting *	MOD-2
	Biological Science, Session E	1-152
9:30	AAPT, Session A	1-154
9:00	Engineering *	1-129

SATURDAY AFTERNOON, MAY 14, 1992

1:00	AAPT, Session B	1-154

* Section Business Meeting to follow this session.

AGRICULTURAL SCIENCE

Friday, 8:15 am - 9:45 am, Room 1-148
SESSION A
E.C. French, University of Florida, Presiding

8:15 am, WELCOME
Agricultural Science Section Chair

8:15 am, AGR-1A Inheritance of in vitro callus growth rate is desmodium. P.A. KROTTJE, D.S. WOFFORD, AND K.H. QUESENBERRY, Agronomy Department, IFAS, University of Florida, Gainesville, FL 32611. A study of the genetic basis of in vitro characteristics in desmodium was conducted as part of a broad effort to apply the methods of biotechnology to the improvement of tropical forage legume species. In previous work substantial variation among inbred lines in callus growth rates and regeneration abilities were observed, with rapid callus growth associated with low regeneration frequency. Three F1 hybrids were generated from four inbred parental lines and selfed though the F_3 generation. Seeding hypocotyls from the parents, 148 F_2 and 583 F_3 progeny were cultured on L2 callus induction medium for 28 days and callus wet weights determined. Callus growth rate was found to be moderately heritable despite high levels of environmental and nonadditive genetic variance. Preliminary analysis of shoot regeneration in the F_2 and F_3 generations indicates that it will be possible to select for genotypes with both rapid callus growth and high regeneration frequency.

8:30 am, AGR-2A Seed-Related Characteristics of Pearl Millet x Elephantgrass Amphiploid Hybrids. D.A. DIZ AND S.C. SCHANK, University of Florida, IFAS, Department of Agronomy, Gainesville, FL 32611. Lack of high quality seed in elephantgrass (*Pennisetum purpureum*) and its hybrids to pearl millet (*P. Glaucum*) has limited their use for forage or biomass. Development of a high quality, seed-propagated pearl millet x elephantgrass hexaploid hybrid, would be highly desirable. The objectives of this study were: A) To characterize seed-related traits from the selfed progeny of seven hexaploid hybrids; and B) To determine whether seed size had any influence on these traits. Traits studied included number of panicles per plant, days of flowering, panicle length, seed set, seed production, weight of 100 seeds, and seed germination. Genetic differences were found among the progeny of the seven hybrids. Differences were also found between plants derived form large- and small-seed lots within sub-groups. Plants descended from larger seed had better growth and seed-related characteristics, which resulted in more desirable plants.

8:45 am, AGR-3A Analysis of Divergent Selection for Pod Color in Pigeonpea. P.E. REITH AND K.L. BUHR, University of Florida, Institute of Food and Agricultural Sciences, Department of Agronomy, Gainesville, FL 32611. Pigeonpea (Cajanus cajan L. Millsp.) has been imported into the United States to meet domestic demand for the pulse. Production of this tropical crop is limited in the U.S. Efforts to adapt this "oft-cross pollinated" tropical crop to north central Florida have resulted in several advanced lines. While uniform for certain traits, these lines were heterogeneous for pod color. Divergent selection, using recurrent mass selection procedures, was practiced in a heterogeneous population of plants with green pods and plants with maroon-colored pods. Two cycles of selection for green pod color and one cycle for maroon-colored pods resulted in near homogeneity in each of the two populations.

9:00 am, AGR-4A Growth and Yield of Pigeonpea as Influenced by Planting Date and Plant Population. S. BACHREIN AND G.M. PRINE, University of Florida, Agronomy Department, Gainesville, FL 32611. Planting date and plant population effects were studied on pigeonpea (*Cajanus cajan* (L.) Millsp) at Gainesville, Florida in 1989. The objective was to identify improved management practices and genotypes through a better understanding of the growth of an indeterminate cultivar 'Norman' and a determinate line FL 99WW. Canopy light interception, radiation use efficiency (RUE), and other growth and yield attributes were measured. June planting date increased the seed yield and growth attributing characters over July planting. Increasing plant population (30,000 to 120,000 plants ha^{-1}) resulted in increased total biomass accumulation m^{-2} and leaf area index (LAI), but reduced the accumulation of dry matter in leaf and stem plant^{-1}, and these contributed to the reduced harvest index (HI) and seed yield.

9:15 am, AGR-5A Optimal Plant Spacings for Late Season Tropical Corn Production. T.A. LANG AND R.N. GALLAHER, University of Florida, Institute of Food and Agricultural Sciences, Agronomy Department, Gainesville, FL 32611. Tropical corn (Zea mays) produces acceptable yields of quality silage or grain when double-cropped after wheat (Triticum aestivum) or spring season corn. The objective of this study was to determine the equidistant plant spacing for maximum whole plant and grain yields of late-planted tropical corn. The experiment was conducted near Jonesville, FL in 1989 and 1990 on an Arrendondo fine sand (Grossarenic Kandiudult). Six equidistant spacings (15 to 91 cm) and two row configurations were evaluated for 'FLA-SYN1-2', an experimental tropical synthetic corn cultivar. Highest grain and whole plant dry matter yields of 2.4 and 8.5 Mg ha^{-1}, respectively, were obtained at 30 cm spacing. Whole plant yields of a double row configuration were higher than single row yields and comparable to the 30 cm spacing.

9:30 am, AGR-6A Growth and Nitrogen Content of Lupine, Crimson Clover and Hairy Vetch. R.N. GALLAHER, University of Florida, Institute of Food and Agricultural Sciences, Agronomy Department, Gainesville, FL 32611. Use of winter legumes in multiple cropping is important to help sustain agricultural production and the environment. The objective of this research was to determine dry matter (DM) distribution among plant parts, DM and N partitioning and the rate of growth of 'Tift Blue' lupine (Lupinus angustifolius), 'Tibie' crimson clover (Trifolium incarnatum) and hairy vetch (Vicia villosa). Crops planted 9 November 1990 were collected eight times in 1 m^2 plots from 27 to 171 days after planting in completely randomized plots for analysis. Maximum total plant DM was 1810, 1120, and 660 g m^{-2} for lupine, crimson clover and hairy vetch, respectively. Nitrogen content peaked at 32.9, 21.7, and 24.0 g m^{-2} for lupine, clover and vetch, respectively. The DM to N content ratio throughout the growth cycle was in the order of lupine > clover > vetch.

9:45 am, BREAK

Friday, 10:00 am - 11:30 am, Room 1-148
SESSION B
R.N. Gallaher, University of Florida, Presiding

10:00 am, AGR-7B The Relationship Between Leaf Nutrition of Two Soybean Cultivars and Rates of Nematicide. S. EDME (1), R.N. GALLAHER (1), R. McSORLEY (2), AND D.W. DICKSON (2), (1) Institute of Food and Agricultural Sciences, Department of Agronomy and (2) Department of Nematology, University of Florida, Gainesville, FL 32611. The effects of the nematicide aldicarb at four rates (0, 0.56, 0.84, 1.12 kg a.i. ha^{-1}) on the leaf element composition of two soybean (*Glycine max* (L.) Merrill) cultivars ('Leflore' and 'Davis') were investigated. The objective was to determine changes in the nutrient concentrations of soybean leaf tissue in relation to cultivars and the rates of aldicarb. A factorial experiment in a randomized complete block design with 4 replications was used to analyze leaves at the R2 stage for N and minerals. Cultivar effect was in general more important ($p<0.01$) than the level of nematicide. Leflore accumulated more N, P, K, Mn, and Zn in its leaves than Davis which, stunted from nematode damage, had more Ca, Mg, and Cu. Only N, P, and Mg concentrations were affected by nematicide rates.

10:15 am, AGR-8B Soybean Cultivar Performance in a *Heterodera glycines* "Race 4" Infested Field. C.K. HIEBSCH (1) AND R.A. DUNN (2), (1) 304 Newell Hall, (2) Building 78, University of Florida, Gainesville, FL 32611. Outside Florida, repeated production of soybean cultivars resistant to race 3 of *Heterodera glycines* (soybean cyst nematode, SCN) have led to shifts in the population of SCN to other races, generally race 4. Race 4 resistant (R4R) soybean cultivars were often used successfully in these fields. Soybean genotypes which were race 4 susceptible (R4S) and R4R were evaluated during two growing seasons in a field near Marianna in which Kirby soybeans (a race 3 resistant and R4S cultivar) had been badly damaged by SCN. Later maturing lines, appropriate for Florida, were also included. In the first year, yields averaged 1.7 Mg ha^{-1} for seven R4R cultivars, 1.6 Mg ha^{-1} for ten R4R late maturing breeding lines, and 0.8 Mg ha^{-1} for nine R4S cultivars. In the second year, average yields were 3.0 Mg ha^{-1} for three R4S cultivars. Mature female cysts of SCN (number/100 cm^{-3} of soil) at the end of the first growing season were 56 for 17 R4R and 232 for nine R4S genotypes, respectively.

10:30 am, AGR-9B Tall Bunch Grasses as Potential Energy Crops under Sewage Effluent Irrigation and on Phosphatic Settling Pond Clays, G.M. PRINE (1), D.B. SHIBLES (2) AND J.A. STRICKLER (2), (1) University of Florida, Agronomy Department, Gainesville, FL 32611, and (2) Mined Lands Research/Development Project, Bartow, FL 33830. Tall bunch grasses were planted on city sewage effluent irrigated spray fields at Leesburg, FL. Average annual dry matter yield over two seasons, 1985 and 1986, was 52.0, 37.0 and 32.8 Mg ha^{-1} for PI 300086, N51 and Merkeron elephantgrass (*Pennisetum purpureum*) respectively, and 21.7 Mg ha^{-1} for L79-1002 energy can (*Saccharum* sp.). Tall grasses were grown in Polk County on phosphatic settling pond clays fertilized with 112 kg N ha^{-1} yr^{-1} for four seasons, 1987-90. The average annual dry matter biomass yield was 36.2 and 45.2 Mg ha^{-1} for PI 300086 and N51 elephantgrass, 42.5 and 49.0 Mg ha^{-1} for L79-1002 and US72-1153 energycane and 49.7, 52.2 and 56.2 Mg ha^{-1} for US78-1009, US56-9 and CP72-1210 sugarcane (*Saccharum* sp.). Dry tall grass biomass contains about 45% of the energy contained in same weight of oil so 0.326 Mg of dry biomass has energy equal to a

40 gallon barrel of oil. It is concluded that sewage effluent spray fields and phosphatic clays are prime sites for growing tall bunch grasses for energy use.

10:45 am, AGR-10B Rhizoma Peanut Establishment in Phosphatic Clay. E.C. FRENCH, G.M. PRINE, E.A. HANLON, J.A. STRICKER, D.B. SHIBLES, AND C. RIDDLE, University of Florida, Agronomy Department, Gainesville, FL 32611. Perennial peanut (cv. Florigraze) shows promise as a high value forage legume grown on phosphatic clay. Establishment practices on these clay soils must be defined before promoting the commercial production of perennial peanut under these conditions. A study conducted in 1991 was designed to determine the optimal planting method (sprigs or sod) and sprigging rate or sod spacing needed to achieve rapid stand coverage and maximum early yield. Rates of 1.4, 2.8, 4.2 and 5.6 m^3 h^{-1} of rhizomes were planted in plots 6 x 3.7 m and sod pieces planted at spacings of 0.46, 0.92, 1.39, and 1.8 m distance apart. Spread data was determined by grid counts of emerged shoots following approximately 10 months of development. A planting rate of 1.4 m^3 h^{-1} resulted in the lowest % coverage (63.5), while 2.8 m^3 h^{-1} had the highest % (72.6). Coverage between sod pieces spaced 0.46 m apart, averaged 85.6%, decreasing to a low of 21.6% at widest sod spacing. Dry matter yield for sprig treatments increased linearly from 538 kg h^{-1} for the 1.4 m^3 h^{-1} planting rate to 1003 kg h^{-1} for the maximum planting rate of 14 m^3 h^{-1}. Closely spaced sod (0.46 m apart) achieved an average dry matter yield of 2810 kg h^{-1} decreasing linearly to 1274 kg h^{-1} for sod spaced 1.8 m apart.

11:00 am, AGR-11B Rhizoma Peanut Establishment as Influenced by Grazing Management and Stored Carbohydrate. R.W. RICE, L.E. SOLLENBERGER, K.H. QUESENBERRY, E.C. FRENCH, AND G.M. PRINE, University of Florida (IFAS), Agronomy Department, Gainesville, FL 32611. Rhizoma peanut (Arachis glabrata Benth) is a persistent, high-quality forage legume well suited to Florida environments. The effect of grazing management on 'Florigraze' establishment was evaluated by planting rhizomes dug from pastures previously subjected to severe, moderate and lenient grazing stress. At planting, these different rhizome populations exhibited a wide range of total non-structural carbohydrate (TNC) concentrations (52-302 g TNC kg^{-1}) but by season end, concentrations were similar even though rhizome and shoot production differed greatly across treatments. Initial carbohydrate pool (g TNC m^{-2}) was related to season end rhizome DM ($r^2=0.62$), shoot DM ($r^2=0.63$), percent coverage ($r^2=0.82$), and early second season regrowth ($r^2=0.76$). Similar 1991 establishment trends using new rhizome planting material are also likely related to differences in stored carbohydrate.

11:15 am, AGR-12B Phytotoxicity Screening of Four Post-emergence Applied Herbicides on Seven Spices. J.R. ESPAILLAT, S.H. WEST, E.C. FRENCH, D.L. COLVIN, Agronomy Department, IFAS, University of Florida, Gainesville, FL 32611. A herbicide screening experiment was carried out to determine the phytotoxicity (phyto) effect of norflurazon (NOR), simazine (SIM), bentazon (BEN), dicamba (DIC) and a nontreated control on sage (*Salvia Officinalis* L.), pot marjoram (*Origanum onites*), wild marjoram (*Origanum vulgare* subsp. vulgare), lavender (*Lavandula angustifolia*), winter savory (*Satureja montana*), rosemary (*Rosmarinus officinalis* L.), and sweet marjoram (*Origanum mejorana*). A strip-split plot design with four reps was sprayed with each herbicide at three rates. Phyto rating was determined 21 days after application. Differences between herbicides, rates and spices was significant. Interactions between each pair of factors and between the three treatments were significant. NOR proved to be the least phytotoxic herbicide. NOR was safe at 1/2 x in wild marjoram, lavender, winter savory, rosemary and sweet marjoram and at 1 x in lavender and rosemary; BEN at 1/2 x in sage, pot marjoram, winter savory and rosemary, and at 1 x in rosemary; and DIC at 1/2 x in sage, rosemary and sweet marjoram demonstrated potential. SIM killed the exposed plants at all rates.

11:30 am
SECTION MEETING: AGRICULTURAL SCIENCE
C.K. Hiebsch, Presiding

ANTHROPOLOGICAL SCIENCES

Friday, 8:45 am - 10:15 am, Room 1-149
SESSION A: Learning to Live Together
L.S. Lieberman, University of Florida, Presiding

8:45 am, ANS-1A Culture, Learning and Human Motivation: A Theory. VANCE GEIGER, Department of Anthropology, University of Florida, Gainesville, FL 32611. One of the basic tenants of Anthropology is that culture is learned. To the degree that culture determines human behavior then, human behavior is determined by how people learn and what they learn. This paper presents a theory of human motivation in which human behavior is based on maintaining the efficacy of learned associations. Ethnographic examples are provided from Papua New Guinea and a Southeast Asian refugee camp.

9:00 an, ANS-2A Social Reproduction of Racism among Poor Whites in Florida. J.W. GIBSON-CARPENTER, Department of Anthropology, University of Florida, Gainesville, FL 32611. A study of a poor white community supports certain sociological theories of racism (intergenerational cultural transmission, privilege protection, dehumanization to legitimize exploitation) but shows the important roles racism plays in 1) defending against institutional assaults on the social status of poor whites and 2) providing an "inverse" ethnic identity which promotes community cohesion. Additional contributing factors include both the lack of institutional and experiential challenges to and implicit government and media support for ideological racism.

9:15 am, ANS-3A Changing Perceptions towards Indigenous and Rural Peoples: the Convergence of Environmental Issues and Folk/Indigenous Interests. L.C. FORLINE, University of Florida/Department of Anthropology, Gainesville, FL 32611. World-wide trends in ecological destruction have caused concern and alarm in the development community, and as a consequence environmental studies have directed their attention to the conservation and management of natural resources. Scientists stress that indigenous and folk peoples of tropical countries are effective managers of natural resources. This paper argues that the concern for environmental issues is converging with indigenous interests and consequently researchers have argued that indigenous and folk societies of the tropics have developed resource strategies that are well-adapted to their respective environments. This outlook has helped shape a new ideological perspective which has guided environmental groups to embark on more intensive studies of indigenous/folk knowledge and to influence public opinion. Environmental groups have pressured legislatures and multilateral development banks to reorient development packages towards strict environmental guidelines that embrace indigenous/folk interests.

9:30 am, ANS-4A Signed Languages and Descriptive Linguistics: An Introduction to Polish Sign Language. MICHAEL A. FARRIS, Department of Anthropology, University of Florida, Gainesville, FL 32611. Sign language research is scarcely more than thirty years old. Surprisingly little of it has dealt with the grammatical structures of different signed languages, an area usually handled in anecdotal and impressionistic ways. This is partly due to changes in the field of linguistics and partly due to the nature of signed languages themselves. This paper examines some possible ways of analyzing signed language structure, focusing on the author's initial field experience with Polish Sign Language (PJM).

9:45 am, ANS-5A What is a Syllable? J. SIBENTHALER, Linguistics Program, Anderson Hall, University of Florida, Gainesville, FL 32611. The concept of the syllable is used frequently in linguistic theory, but its definition is still a topic of debate. Some past attempts to define the syllable will be examined. Suggestions for future research will be offered.

10:00 am, ANS-6A The Scopes Evolution Trial, 65 Years Later. J. STRAYER, 6 Margaret Road, Ormond Beach, FL 32176, Daytona Beach Community College, Daytona Beach, FL 32114. The events of the Dayton, Tennessee, Scopes trial on teaching evolution in public schools is well documented, but in the 65 years since, it is the inaccurate movie "Inherit the Wind" that has been the source of information about the famous "monkey" trial. With our present school systems sometimes facing problems in regard to teaching evolution, a more accurate account of the events should be presented. Florida had a strong connection to the trial. The ACLU was looking for a test case. Florida had passed an anti-evolution resolution two years before because of the influence of William J. Bryan, who was a Florida realtor, former Secretary of State, and fundamentalist minister. A resolution is not a law, so he used his influence in Tennessee to get an anti-evolution law passed. Now, the ACLU had a test case. The resolution, the law, and the results will be discussed.

10:15 am, BREAK

Friday, 10:30 am - 11:45 am, Room 1-149
SESSION B: Physical Anthropology and Archaeology
L.S. Lieberman, University of Florida, Presiding

10:30 am, ANS-7B Infant Vocalizations and Systematics in Hominid Evolution. BRYAN ST. LAURENT, Florida Governor's Council on Indian Affairs, Inc., P.O. Box 10449, Tallahassee, FL 32302-2449. The paper summarizes a critique of the application of Haeckel's biological theory of recapitulation to relationships between infant vocalizations and the origins of music. Recapitulation (the ontogenetic method) is evaluated as one of the two methods by which biologists use song (behavior) to estimate phylogeny, the second method being outgroup comparisons. The applications of the two methods so far to birdsong and primate vocalizations is reviewed to provide a context for application to hominid evolution.

10:45 am, ANS-8B Skeletal Trauma in Forensic Research: Implications for Archaeologists. K.J. WINLAND (1), A. ROSS (1), M. GROH (1), M.Y. ISCAN (1), AND J.H. DAVIS (2), (1) Florida Atlantic University, Department of Anthropology, Boca Raton, FL 33431, (2) Medical Examiner Department, Metropolitan Dade County, 1 Bob Hope Road, Miami, FL 33136. Archaeology has much to gain from studies of trauma observed in skeletal remains of documented cause of death. Therefore, the purpose of this paper is to show the characteristics of wounds in order to relate the type of trauma produced to particular weapons. The remains of 370 skeletons from the Joseph H. Davis and FAU Collections were examined. Where trauma was present, 65% could be attributed to gunshot wounds, 22% blunt trauma, 9% cutting injuries, and 4% could not be classified. The preliminary observations indicated that trauma caused by high velocity projectile weapons produced distinctive characteristics that could be identified as such. Blunt and sharp trauma, on the other hand, were not easy to associate with a particular weapon. In this case, the difficulty arises from the effects of taphonomic factors and digenesis. It is concluded that skeletal biologists dealing with archaeological human remains should be cautious before attributing cause of death.

11:00 am, ANS-9B Projectile Trauma in the Human Skeleton: Estimating Size and Type. K.J. WINLAND (1), M. GROH (1), A. ROSS (1), M.Y. ISCAN (1), AND J.H. DAVIS (2), (1) Florida Atlantic University, Department of Anthropology, Boca Raton, FL 33431, (2) Medical Examiner's Department, Metropolitan Dade County, 1 Bob Hope Road, Miami, FL 33136. One of the major difficulties facing forensic scientists is the determination of the nature of a projectile from wounds in isolated skeletal remains. Therefore, the purpose of this paper is to match the caliber and type of projectile to wounds in the human skeleton. The remains of over 370 skeletons of the Joseph H. Davis and the FAU Collections were examined, and 65% exhibited evidence of trauma associated with firearms. The preliminary results indicate that generalizations could be made about bullet caliber and type from the size and shape of the entry wounds. Bullet wounds from handguns were relatively easy to assess, especially in the cranium, but the generally greater force and velocity produced by rifles and shotguns caused much more extensive damage. Many factors such as distance from the weapon, and location of the wound complicate the final diagnosis.

11:15 am, ANS-10B Characterizing El Nino Disasters and Cultural Change, Ilo, Peru: A Preliminary Report. DENNIS SATTERLEE, Department of Anthropology, University of Florida, Gainesville, FL 32611. During the 14th century AD, in the Osmore Drainage, Ilo, Peru, the largest flood yet identified in all of South America swept across the coastal and valley sites of the Chiribaya Culture virtually destroying everything in its path. Preliminary observations are presented, characterizing the prehistorical disaster and its potential cultural ramifications.

11:30 am, DISCUSSION

Friday, 3:00 pm - 4:30 pm, Room 1-149
SESSION C: Gerontology and Anthropology
M. Gutierrez-Mayka, University of South Florida, Presiding

3:00 pm, ANS-11C Fulfilling the Needs of Caregivers of Elderly Demented Patients: An example of Unplanned Role Negotiation in a Community Health Intervention Project. MARCELA GUTIERREZ-MAYKA AND J.N. HENDERSON, Suncoast Gerontology Center, University of South Florida, 12901 Bruce B. Downs Blvd., MDC Box 50, Tamp, FL 33612-4799. A project designed to implement family support groups for minority caregivers of demented patients is discussed. At least six different roles were played, sometimes simultaneously, by the project's implementors whose own background was in anthropological research. Of those six roles, the "social worker" role was the most unexpected, and ultimately the most vital to the success of the project given the needs of the subjects involved.

3:15 pm, ANS-12C Ethnocultural Themes in Caregiving to Alzheimer's Disease Patients in Hispanic Families. J.N. HENDERSON AND MARCELA GUTIERREZ-MAYKA, Suncoast Gerontology Center, University of South Florida, 12901 Bruce B. Downs Blvd., MDC Box 50, Tampa, FL 33612-4799. Clinical intervention can be more effectively delivered to Hispanic elderly when symptoms and behaviors are understood in the ethnocultural themes in caregiving to Hispanic dementia patients: 1) intensity of sex-role division of labor 2) stigma accruing to family, and 3) age-cohort broker role of adult children of elderly caregivers.

3:30 pm, ANS-13C Public Health and Elder Dominicans. SUSAN PAPPAS, Department of Anthropology, University of South Florida, 4202 E. Fowler Ave., Tampa, FL 33620. The following paper is based on a six month study in the Dominican Republic. The research focused on documenting the way older Dominicans enter into the public health system, the types of services available to them, and the barriers to accessing those services. The role and importance of social support systems in the lives of elder Dominicans, and the consequences of the absence of those supports were also examined. Case studies derived from the research are used in the discussion.

3:45 pm, ANS-14C Diet Adequacy in a Sample of Older African American Women with Diabetes. L.S. LIEBERMAN, C.K. PROBART AND N.E. SCHOENBERG, University of Florida, Gainesville, FL 32611. A twenty-four hour dietary recall and a quantitative food frequency were administered to 10 women with a median age of 68 years who had non-insulin dependent diabetes. The results indicate intakes of fat (36.9%), protein (16.1%), carbohydrates (46.6%) of the total calories. This is comparable to the U.S. national sample. Caloric intake was higher for the 24-hour recall. Mean intakes were adequate for most nutrients, although there was a wide range with some women reporting low intakes for energy, protein, calcium and iron.

4:00 pm, DISCUSSION

4:15 pm
SECTION MEETING AND AWARDS PRESENTATION
L.S. Lieberman and M. Gutierrez-Mayka, Presiding

BIOLOGICAL SCIENCES

Friday, 8:45 am - 12:00 am, Room 1-154
SESSION A: Marine Biology I
Duane Phillips, Mote Marine Laboratory, Presiding

8:45 am, BIO-1A Temporal Comparison of Hillsborough Bay Phytoplankton Populations. B. KELLY, City of Tampa, Bay Study Group, 2700 Maritime Blvd., Tampa, FL 33605. Since July 1981 the City of Tampa's Bay Study Group has been conducting a monthly sampling program in Hillsborough Bay. Included in this program is the enumeration and taxonomic study of phytoplankton. In April 1989 the survey was expanded to include weekly sampling as well. The benefits of a weekly v. monthly sampling regime are now being evaluated in order to determine whether short term fluctuations in the phytoplankton population can be detected without weekly sampling.

9:00 am, BIO-2A The Effect of Iron on Phytoplankton Growth. M.A. YU, O.M. POO AND B.J. STEWART, Barry University, Miami, FL 33161. Previous studies have suggested that iron enhances phytoplankton growth. Preliminary studies performed in March 1991 proved to be inconclusive. In October 1991, a ten day study was conducted on cultures containing varying concentrations of dissolved ferric citrate. Daily measurements included spectrophotometric absorbance of the organisms, pH, and concentrations of dissolved iron, nitrate, and phosphate. The results indicated that there is an optimum concentration of iron needed for phytoplankton growth. Concentrations below and above this optimum produce cultures with decreased organism density. (Research supported in part by NOAA).

9:15 am, BIO-3A An Evaluation of the Methods for Assessing Changes in the Coverage of Seagrass Beds Over Time. W. SCHLESE HEIDELBAUGH AND WALTER G. NELSON, Department of Oceanography, Ocean Engineering and Env. Sci., Florida Institute of Technology, Melbourne, FL 32901. Destructive (cores) and nondestructive (quadrant surveys) methods were used to estimate changes in seagrass bed density. Statistical methods were applied to evaluate which survey techniques may be best in detecting differences in seagrass cover in space and time. Coefficients of variation (CV) were determined for cores collected from six stations during seven sampling periods. CV's were also calculated for quadrant surveys taken during nine sample collections from the same six locations. The CV's were used to estimate the number of replicate samples needed to be 75% and 90% certain of detecting a 10% and 50% difference between two of the six means at the 5% level of significance.

9:30 am, BIO-4A Trend Analysis of Submerged Aquatic Vegetation (SAV) in the Vicinity of a Thermal Effluent. L.K. DIXON (1), E.F. BLOK (2), AND M.H. COLBY (2), (1) Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota 34236, (2) Geonex-St. Petersburg Division, 8950 Ninth St. N., St. Petersburg, FL 33702. Mapping of SAV in the Anclote estuary via aerial photography evaluated net change in spatial coverage for selected time periods (1981-1990) without regard to species composition. Trends in cover, both in areal extent and apparent density of SAV, were examined as a function of thermal regimes, power plant operating history, and other potential impacts such as region-wide improvements in water quality, sedimentation, and winter desiccation. Varying photo quality between time periods was taken into account. Areas of gain in cover predominated over the entire study area and there were no losses linked to temperature regimes. One area of loss within the discharge appeared to be sediment related.

9:45 am, BIO-5A Projected Seagrass Cover in Hillsborough Bay (Tampa Bay) by Year 2000. J.O.R. JOHANSSON, City of Tampa, Bay Study Group, 2700 Maritime Blvd., Tampa, FL 33605. Submerged seagrass has returned to Hillsborough Bay after several decades of apparent absence. The return of seagrass and improvements in classical water quality parameters can be linked to a large reduction in nitrogen input to the bay from domestic wastewater and fertilizer industry sources. Water quality improvements and sparse seagrass revegetation were seen in the mid 1980's, a few years after the reduction. Water quality has since remained relatively fair and stable. In contrast, seagrass revegetation is now occurring at a logarithmic pace, indicating that it is not yet in balance with the improved water quality. A simple projection suggests that Hillsborough Bay seagrass cover in year 2000 may be near 1000 ha, or similar to estimated cover in 1950 before several large losses occurred. The potentially long time-lag (+15 years) between water quality change and resulting seagrass coverage should be considered when evaluating past, and planning future, Hillsborough Bay and Tampa Bay management strategies.

10:00 am, BREAK

10:15 am, BIO-6A Effects of the Anclote Power Plant Thermal Effluent on the Seagrass *Thalassia testudinum*. J.K. CULTER, Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota, FL 34236. The Anclote Power Plant located on the Florida Gulf Coast has been in operation since 1974. Helper cooling towers were constructed in 1981. *Thalassia* condition was evaluated with shoot density counts, wet and dry blade and rhizome biomass, rhizome length, and blade length, width and area. There were seasonal and station variations in biomass with strong negative correlations with temperature. There was a significant negative correlation of biomass with depth. For comparable depths, shoot densities were typically lowest at the thermally affected stations. Blade widths, total blade area and rhizome length were also generally smaller at thermal stations. Carbohydrate reserves, measured as a ratio of rhizome biomass to length, were also noted as lower at the thermal stations during spring and summer and to a lesser extent for fall collections. There was evidence that shoot densities had increased from 1976, particularly at the most thermally affected shallow and mid depth stations.

10:30 am, BIO-7A Thermal Effects on Maximum Epiphyte Biomass of Thalassia testudinum from the Anclote Anchorage, Florida. JAY R. LEVERONE, Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota, FL 34236. Differences in maximum epiphyte biomass on exposed blades of turtle grass were investigated along thermal gradients in the vicinity of the Anclote Power Plant during spring, summer and fall, 1990. Mean seasonal biomass was highest during spring (45.01 ± 14.95 mg dry wt/cm^2 blade area) and lowest during summer (23.69 ± 10.91 mg dry wt/cm^2 blade area). Shallow, nearshore stations generally had lower epiphyte biomass than deeper stations. Depth correlations were stronger overall than temperature relationships. Shallow stations along the thermal transect, however, supported higher epiphyte loads similar to deeper control stations. These seasonal observations may be attributable to the growth pattern of Thalassia, whose higher growth rates during warmer months provide a relatively temporary substrate for epiphytes to settle and grow.

10:45 am, BIO-8A The Effects of Hyposaline Conditions on Caulerpa prolifera. W.M. AVERY, City of Tamp, Bay Study Group, 2700 Maritime Blvd., Tampa, FL 33605. In September 1988, salinities in parts of Hillsborough Bay were lowered to 1-2 ppt following a 25 year rainfall event and hyposaline conditions persisted for nearly a month. Within a month following the rainfall, nearly 200 hectares of subtidal flats which had contained the coenocytic alga, Caulerpa prolifera, were barren. Laboratory tests indicate that in short term exposure (less than 48 hours) to salinities of less than 10 ppt, C. prolifera O_2 production is inhibited, chlorophyll content in the thallus is reduced, and plant biomass decreases.

11:00 am, BIO-9A Effects of Petroleum on Rhizophora mangle and Avicennia germinans Seedlings. E. PROFITT, D.J. DEVLIN AND M. LINDSEY, St. Petersburg Junior College, St. Petersburg, FL 33710. Two studies of the effects of oil on mangrove seedlings were conducted. First, R. mangle propagules were collected from oiled (result of an oil spill) and unoiled areas of south Pinellas Co. Propagules were scored as to High (>50%) or Low (<50%) surface area oil cover. Propagules were planted in potting soil and watered regularly. Preliminary results suggest that heavy oiling slightly reduced survival and reduced growth while low oiling had no negative effects on seedling survival and growth. Second, R. mangle and A. germinans planted seedlings were subjected to one-time and weekly oiling of the sediment, but not on the above-ground portion of the plant. Preliminary results suggest A. germinans seedlings are not tolerant of oil and suffer high mortality. R. mangle seedlings survive, but growth is suppressed.

11:15 am, BREAK

11:30 am
BUSINESS MEETING
David Bruzek, Florida Power Corp., Presiding

Friday, 8:45 am - 12:00 am, Room 1-152
SESSION B: ECOLOGY
David Sumpter, HDR Engineering, Presiding

8:45 am, BIO-10B Characteristics of Benthic Macroinvertebrate Communities of the Tidal Freshwater Region of the Suwannee River. ROBERT A. MATTSON, Suwannee River W.M.D., Rt. 3, Box 64, Live Oak, FL 32060. Macroinvertebrates were sampled at one station in the tidal freshwater region of the Suwannee River estuary over a two year period, using artificial substrate, polar grab and qualitative dip-net samples. The community includes a mix of freshwater species (various insect groups, oligochaetes, crustaceans and molluscs) and estuarine forms such as *Neritina reclivata, Taphromysis bowmani, Callinectes sapidus* and *Uca minax*. Insects (primarily chironomidae) generally comprised the majority of the species richness and density on the Hester-Dendy samplers, with amphipod crustaceans and gastropod molluscs forming most of the remainder of the artificial substrate community. Invertebrate abundance in the polar samples was dominated by the Asian clam, *Corbicula fluminea*, with oligochaetes forming the second most abundant group. Qualitative samples were primarily dominated by the olive nerite (*N. reclivata*).

9:00 am, BIO-11B Insects as Biogeographical Indicators on the Brooksville Ridge. M. DEYRUP, Archbold Biological Station, P.O. Box 2057, Lake Placid, FL 33852. Preliminary studies suggest the north and south portions of the Brooksville Ridge are faunistically divergent. Melanopus rotundipennis, a wingless grasshopper widespread in the uplands of north and central Florida, has its only markedly divergent population on the south Brooksville Ridge. Two species of ants show links to the south Lake Wales Ridge. These insects are likely to be the first examples of a number of narrowly restricted endemic species and subspecies on the Brooksville Ridge south of the Dunellen Gap.

9:15 am, BIO-12B Distribution of the Bluebarred Pygmy Sunfish, Elassoma okatie. FRANKLIN F. SNELSON, JR., Department of Biology, University of Central Florida, Orlando, FL 32816. Elassoma okatie is an uncommon pygmy sunfish confined to lowland blackwater habitats in extreme southern South Carolina. Previous collection sites were confined to tributaries of the Savannah, New and Edisto rivers in three counties. A survey conducted in 1989 discovered new populations at five additional sites, including two new drainage systems, the Broad and Combahee. The species occupies two rather distinct habitat types, blackwater swamp streams and roadside ditches. Where it occurs, the species may be rare or common; but it is absent from many sites where habitat appears to be suitable. Length frequency data suggest that Elassoma okatie is an "annual" species. This may explain its spotty distribution and render it more susceptible to local extirpation.

9:30 am, BIO-13B Control of Hydrilla in Five Central Florida Lakes Utilizing Triploid Grass Carp and Herbicides while Maintaining Native Littoral Vegetation. J.A. OSBORNE, E. COTSENMOYER, AND J. HOWELL, Department of Biology, University of Central Florida, Orlando, FL. The purpose of this study was to evaluate the use of triploid grass carp used in conjunction with aquatic herbicides to control hydrilla without loss of shoreline vegetation. Since grass carp undergo a reduction in their feeding rate with an increase in size, large fish were used to lessen their impact on shoreline plants. Stocking rates of 5 fish per acre were sufficient to control hydrilla after the use of aquatic herbicides. Shoreline vegetation was not significantly affected. Even during the third year, hydrilla control continues to be complete. Exclosures placed in the lakes to exclude the grass carp demonstrated that hydrilla control from the aquatic herbicides only lasted from 6 to 10 months.

9:45 am, BIO-14B A Reproducing Population of *Trachemys scripta elegans* in Southern Pinellas County. A.M. HUTCHISON, Eckerd College, 4200 54th Ave. S., St. Petersburg, FL 33711. *Trachemys scripta elegans*, the red-eared slider, occurs naturally north and west of Florida, from West Virginia to New Mexico and extreme northeastern Mexico. However, its widespread use in the pet trade has promoted introduction of reproducing populations of the species at numerous localities in the eastern United States, including at least two in Florida: metropolitan Date County and in Lake Conway, near Orlando. Because of possible effects of introduced populations of *T. s. elegans* on native species, it is important to identify these populations. This report presents evidence that *T. s. elegans* is breeding in southern Pinellas County, Florida.

10:00 am, BREAK

10:15 am, BIO-15B Dispersal of the Seeds of the Tropical Rain Forest Tree Maesa lanceolata, by Two Species of Bulbul. C.G. GRAHAM (1), T. MOERMOND (2), AND K. KRISTISAN (2), (1) Eckerd College, 4200 54th Ave. S., St. Petersburg, FL 33711, (2) University of WI, Madison, WI 53706. This study, conducted in Nyungwe Forest, Rwanada, examines the role of the birds Andropadus tephrolaemus and A. latirostris in dispersing the seeds of the secondary forest tree Maesa lanceolata. By quantifying each species' tree visitation frequency, duration of stay in the tree, and seed passage time, as well as the germination rate of defecated seeds, the relative effectiveness of these birds as dispersers was determined. The data suggest that both species are effective dispersers of M. lanceolata.

10:30 am, BIO-16B Waterbird Use of Rotationally Managed Saltmarsh Impoundments. J.C. ROSIER, Department of Biological Sciences, Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901. This paper presents preliminary results from a study investigating the effects of drawdown manipulation of water levels in impounded mangrove swamps in St. Lucie County, Florida. Water level in one of four cells in a 398 acre impoundment was drawndown three times during summer 1991. In some instances, bird numbers increased as predicted in relation to progressively lower water levels and increasing concentrated food sources during drawdown. However, it is clear that other factors such as rainfall and tidal cycle also play an important role in the number of birds present.

10:45 am, BIO-17B Distribution and habitat use of the Anastasia Island beach mouse (*Peromyscus polionotus phasma*). PHILIP A. FRANK, Department of Wildlife and Range Sciences, University of Florida, Gainesville, FL 32611. Distribution and habitat use of the federally endangered Anastasia Island beach mouse (*Peromyscus polionotus phasma*) were studied on Anastasia Island located in northeast Florida. Beach mice were distributed over the entire length of the island except for a segment of beach where the natural vegetation has been replaced by concrete reinforcement. Densities of beach mice were lower in disturbed habitat adjacent to residential and commercial development compared to undisturbed habitats, probably as a result of habitat loss and the presence of house cats (*Felis catus*). Viable populations of beach mice probably occur only on two public parks located at either end of the island. Beach mice preferred foredune habitat vegetated by sea oats (*Uniola paniculata*) although a range of habitats including oak scrub well inland of the beach were also used.

11:00 am, BIO-18B Effect of Highways on Bobcat Survival and Movement Patterns in Southwest Florida. MELISSA L. FOSTER, Department of Zoology, University of Florida, Gainesville, FL 32611. One objective of the recovery plan for the Florida panther is to decrease their susceptibility to highway mortality. In this study, bobcats were used as a model to evaluate the effect of highways on bobcat and panther movements and home range patterns in southwest Florida. Ten female and 16 male bobcats were fitted with radio-collars and located at regular intervals between 3/9/89 and 6/30/91. Telemetry data revealed a total of 72 crossings of highways and main roads by 10 of the 26 collared bobcats. Female home ranges were generally truncated by highways while males often had home ranges that were bisected by highways. Thus individual bobcats vary in their susceptibility to highway mortality. Subadults and adult males with stable home ranges including roads cross them with some regularity and are particularly vulnerable to death from traffic accidents and hunting.

11:15 am, BREAK

11:30 am
BUSINESS MEETING
David Bruzek, Florida Power Corp., Presiding

Friday, 3:00 pm - 4:30 pm, Room 1-154
SESSION C: Marine Biology II
Larry McEdward, Presiding

3:00 pm, BIO-19C Methodologies for Ecological Monitoring of Hard-bottom Communities along the Florida Keys Reef Tract. M. CHIAPPONE AND K.M. SULLIVAN, University of Miami, Department of Biology, P.O. Box 249118, Coral Gables, FL 33143. A long-term monitoring project has been initiated on two nearshore patch reef sites along the Florida Keys Reef Tract to determine and assess changes in nearshore hard-bottom communities. Specific survey methodologies have been employed to analyze changes in community structure of benthic sessile invertebrates and benthic macroalgae. Two survey methods included: a) species presence and absence lists and b) density and area coverage of benthic invertebrates utilizing belt quadrants. Both patch reefs have been surveyed since 1988 to quantify changes in species richness, density, and area coverage of dominant benthic invertebrates of hard-bottom communities. Belt quadrant data, specifically area coverage, takes into consideration the three-dimensional complexity of patch reefs and accounts for changes in the spatial patterning of benthic invertebrates. The purpose of this study is to develop a protocol for measuring spatial patterning and monitoring reef benthos to detect changes that may be anthropogenic in origin.

3:15 pm, BIO-20C Infaunal Crustaceans of Spheciospongia vesparium at Selected Hardbottom Communities in the Florida Keys. J.M. LEVY AND K.M. SULLIVAN, University of Miami, Department of Biology, P.O. Box 249118, Coral Gables, FL 33124. A long-term monitoring project has been initiated at two near-shore hardbottom communities in the middle Florida Keys that looks at changes in the diversity of the communities over time. This paper looks at infaunal crustaceans surveyed as part of this monitoring project. The infaunal crustaceans of 10 Spheciospongia vesparium (Lamarck, 1814) of different sizes were sorted and classified. The total number and biomass of the crustaceans of each sponge was correlated to sponge volume. The size frequency distribution and spatial patterning of the sponge were also calculated in order to infer on the overall structure of the crustacean community in each site and ultimately of the whole community.

3:30 pm, BIO-21C Comparison of Encrusting Communities along a Turbidity Screen in a Shallow Marine Lagoon. L. PETRUCELLI, T. GUETTLER, P. CLARKE, R. WHITNEY AND J. MONTAGUE, Barry University, Miami, FL 33161. The Marine Resources Development Foundation (Key Largo) maintains a turbidity screen across its habitat lagoon. A three-day study in May 1991 revealed differences in the encrusting communities on the inner and outer surfaces of the screen. The abundances and diversities of solitary and colonial tunicates (Urochordata), tubeworms (Polychaeta: Annelida), and sponges varied according to depth and location on the screen. (Research supported in part by NOAA).

3:45 pm, BIO-22C Ingestion and Assimilation Rates of Experimental Diets Fed to Juvenile Queen Conch, *Strombus gigas*. D.A. MCARDLE, Department of Biology, Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901. Successful queen conch mariculture could be an important component of increasing queen conch populations. Four experimental diets, *Batophora*, *Ulva*, *Laurencia* and detritus were evaluated for their utilization by juvenile queen conch. Assimilation efficiencies and ingestion rates, of the four diets, are described.

4:00 pm, BIO-23C Effects of the Anclote Power Plant Thermal Effluent on Seagrass Associated Infauna. J.K. CULTER AND J.R. LEVERONE, Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota, FL 34236. Seagrass associated infaunal communities were evaluated with respect to thermal and depth gradients in the vicinity of the Anclote Power Plant on the Florida Gulf coast. Species richness, faunal density and composition, diversity and equitability were evaluated for thermal versus control stations. Benthic communities of the area are structured by depth and thermal gradients. Nearshore thermal stations exhibited fewest numbers of taxa, lowest faunal densities, and overall lower species diversity. Nearshore control stations often exhibited faunal characteristics similar to stations near the discharge canal. As a combined result of solar insolation and thermal discharge, water temperature occasionally reached levels reported as lethal by other studies (32-34°C), but these events were of such short duration that a relatively diverse fauna were maintained. Plant operations do not appear to have altered the structure of the indigenous seagrass associated infauna beyond the immediate confines of the discharge canal.

4:15 pm, BIO-24C Seasonality and Abundance of the Tunicate *Bostiobranchus digonas* and its Relationship to Water Quality in Hillsborough Bay, Florida. E.V. PINSON, City of Tampa, Bay Study Group, 2700 Maritime Blvd., Tampa, FL 33605. Three stations, covering sediment types from mud to sand, have been sampled monthly since 1987 using a Standard Ekman dredge. Water quality parameters have been measured with tunicate collections. Surface and bottom chlorophyll^{-a} measurements have been taken since January 1989. *In Vivo* filtration rates demonstrate rapid uptake of phytoplankton biomass and decrease in Chl^{-a} concentrations. High filtration rates, common in solitary asidians, coupled with large tunicate concentrations can lower Chl^{-a} concentrations and produce good water quality in the vicinity of these communities.

Friday, 3:00 pm - 4:15 pm, Room 1-152
SESSION D: Botany
Patricia Dooris, HDR Engineering, Presiding

3:00 pm, BIO-25D Wall Development in *Urena lobata* Pollen. CATHERINE A. TOOZE, Natural Sciences Collegium, Eckerd College, St. Petersburg, FL 33733. Four growth stages of pollen development within the malvacean species *Urena lobata* (Caesar weed) were examined by electron microscopy. Mature pollen is characterized by operculate pores and long, rounded spines. The diameter of the pollen grain, the length of the spines, and the distance between spines and pores increases with each stage of development. The youngest immature pollen is an irregularly-rounded spheroid without spines. In an intermediate stage, the pollen has a spiny oval shape, when mature, it is a sphere. Pollen morphology is useful for taxonomy and the study of its wall development may clarify relationships within Malvales.

3:15 pm, BIO-26D Pollination Biology of Hyptis mutabilis (Labiatae). R.B. HUCK, Department of Natural History, Florida Museum of Natural History, Gainesville, FL 32611. Intricate methods by which pollination is accomplished in the Labiatae reflect a long history of coevolution. Occasionally mint species move from specialized adapted niches to generalized relationships with widespread insect species, and, in so doing, extend their geographic ranges. Hyptis mutabilis, a native species of tropical America, was observed growing in a weedy field south of Gainesville last summer. Close examination revealed that the anthers were held in tension by a hooded labellum and when the flower was visited by Bombus pennsylvanicus the anthers were sprung, sending clumps of pollen onto the insect. A similar mechanism has been described for other members of the tribe Ocimeae in the Labiatae.

3:30 pm, BIO-27D Environmental Tolerance Tests of Carrotwood and Chinese Tallow Confirm Invasive Nature of these Exotic Plants. J. DOUGLAS OLIVER AND GREG JUBINSKY, Department of Natural Resources, Bureau Aquatic Plant Management, 3917 Commonwealth Blvd., Tallahassee, FL 32399. Our study of two exotic plant introductions, carrotwood (Cupaniopsis anacardioides) and the Chinese tallow-tree (Sapium sebiferum) supports the premise that these plants have the potential to become undesirable invaders of many Florida environments. Greenhouse and outdoor tank tests of these species revealed that both can survive North Florida winters, despite their Australian and Asian origins, respectively. Also, they can survive under shade and inundated freshwater conditions as well as brackish water root conditions. However, brackish water caused the loss of leaves, if the plants were inundated. These species appear to be spreading and could continue unless they are controlled. Interested individuals should keep on the lookout for them, and can report observations to (904) 487-2600.

3:45 pm, BIO-28D The Non-management of an Exotic Plant in the St. Marks River. B. BARTODZIEJ, A.J. LESLIE, AND G. JUBINSKY, Florida Department of Natural Resources, 3917 Commonwealth Blvd., Tallahassee, FL 32399. After over a decade of 2,4-D use to control waterhyacinth (Eichhornia crassipes) on the St. Marks River, the State Legislature in 1988 imposed a five-year ban on all herbicide applications. Since then, the waterhyacinth population has become a significant component in the plant community, sometimes exceeding 20 percent cover. Although this plant grows fast, doubling its biomass every 14 days, floods have ultimately controlled waterhyacinth abundance in this system. Peak abundance levels of waterhyacinth have not noticeably impacted water quality or other biota. Quantitative observations have revealed that water-birds use waterhyacinth mats for perching and sometimes feed around the perimeter of mats, but rarely have birds been observed obtaining food from within waterhyacinth mats. The potential exists for an excessive waterhyacinth population under certain environmental conditions. However, because of frequent water level fluctuations, the data to date support a non-management approach for waterhyacinth in the St. Marks River.

4:00 pm, BIO-29D The Effects of Groundwater Withdrawal and Urbanization on the Health of Isolated Freshwater Wetlands in Southwest Florida. T.F. ROCHOW AND P. RHINESMITH, Southwest Florida Water Management District, 2379 Broad St., Brooksville, FL 34609. Studies have shown that groundwater withdrawal in Southwest Florida can adversely affect wetlands. Geologic exploration on a local scale along with biological monitoring is described showing that wetlands overlying geology prone to sinkhole formation are particularly susceptible to loss of wetland biota when water is pumped from underground. Although intensive local-scale investigations may be successful, at the landscape scale it is more difficult to distinguish adverse impacts to wetland health caused by groundwater withdrawal from those caused by land-use alterations. An approach to analyzing factors influencing wetland health in N.W. Hillsborough Co. is described using indexing to measure wetland health and a Geographic Information System to analyze landscape information.

Friday, 3:00 pm - 5:30 pm, Room 1-100
POSTER SESSION

BIO-P1 A Comparison of the Killing Ability of the Related Cactophilic Yeast, Pichia Kluyceri and P. Amethionina. NINETTE LIMA. Poster.

BIO-P2 Yeast Communities in Opuntia Cactus. EDUARDO BUSTILLO. Poster.

BIO-P3 The Killer Factor of Pichia Kluyveri and Pichia Amethionina var Fermmentans from Florida and Antigua. ELVIRE JACQUES. Poster.

BOI-P4 Section Anatomy of the Elasmobranch Chondrocranium. GERALD CONLOGUE (1), BOB GOOGE (2), AND DENNIS POOLE (1), (1) Gulf Coast Community College, Panama City, FL 32401 and (2) Bay Medical Center, Panama City, FL 32402. Poster.

Saturday, 9:00 am - 11:30 am, Room 1-152
SESSION E: Medical Science/Physiology
B.H. Kwa, University of South Florida, Presiding

9:00 am, BIO-30E Identification of Aeromonads Using Polyclonal Antisera Raised Against Outer Membrane Proteins. DANIEL P. FOLEY, DONALD J. MCGAREY, AND DANIEL V. LIM, Department of Biology and Institute of Biomolecular Science, University of South Florida, Tampa, FL 33620. Utilization of both conventional and rapid bacteriological tests often results in the misidentification of *Aeromonas* species as *Vibrio, Plesiomonas*, and *Shigella* species. Correct identification of aeromonads is necessary for the successful treatment of diseases and epidemiological studies of diseases caused by seromonads. Polyclonal antisera raised to the purified outer membrane proteins of *A. hydrophila, A. sobria,* and *A. caviae* have been used to identify the aeromonads to the species level without significant cross-reactivity among the species and other genera. Western blot analysis of the outer membrane proteins of *A. hydrophila, A. sobria,* and *A. caviae* demonstrates a great deal of cross-reactivity among the 3 species. This cross-reactivity among the species becomes apparent with co-agglutination tests and results in 100% cross-reactivity by immuno-dot blot analysis. This evidence may point to the existence of genus- and species-specific antigens.

9:15 am, BIO-31E A survey for the presence of Cryptosporidium and Giardia in Garadia, Venezuela. M.A. PENTELLA, D. TAREN, B.H. KWA, AND A. PENA, University of South Florida College of Public Health, Tampa, FL 33620. Cryptosporidium and Giardia are common agents of diarrhea among immunocompetent individuals, especially children. There have been several reported outbreaks of both these diseases and transmission is by the fecal/oral route. This study uses immunofluorescent antibody to detect both Cryptosporidium and Giardia simultaneously and compares this technique to the modified acid fast stain and the iodine prep for observation of occysts, cysts, and typhozoites. One hundred and fifty-nine stool samples were obtained from residents of Garadia, Venezuela, a remote village in the Andes Mountains in the state of Merida. The stool samples were stored in 10% formalin immediately after collection, and concentrated using the Formalin/Ethyl Acetate method. The prevalence of Giardia was determined to be 22% and the prevalence of Cryptosporidium was 6.9%.

9:30 am, BIO-32E Classifications of Vertebral Fractures in Natural Animal Models. MIKE O'NEAL, TIM GANEY, JOHN A. OGDEN, Shriners Hospital, Tampa, FL 33612.

9:45 am, BIO-33E Ryanodine/Theophylline Interactions on Muscle Fiber Volume. B. REMUS, A. PARET AND E.T. HAYS, Barry University, Miami, FL 33161. Ryanodine (100uM) and theophylline (2mM) both alone and in combination reduce high energy phosphate levels in isolated frog sartorius muscle. These agents also, on a wet weight basis, increase muscle total creatine (creatine phosphate plus free creatine) contents. Measurements of dry/wet weight ratios were performed under the same conditions as those used for metabolite measurements. The dry/wet weight results suggest these two agents increase rather than decrease muscle fiber volume. Supported by NIH-NIGMS MBRS Program, Barry University.

10:00 am, BIO-34E Ryanodine versus Theophylline-induced Depletion of Energy Contents in Isolated Amphibian Muscle. K. SANCHES, A. ACKERMAN, C. VERRIER AND E.T. HAYS, Barry University, Miami, FL 33161. The effect of high and low levels of ryanodine on theophylline-induced energy reduction was studied in isolated frog sartorius muscle. Whereas low doses of ryanodine did not change high energy phosphate contents, high levels (100uM) reduced resting energy contents. Theophylline in the presence of ryanodine caused further depletion. Whereas theophylline-induced depletions are prevented by procaine, neither ryanodine nor ryanodine plus theophylline-induced reductions were prevented by procaine. Supported by NIH-NIGMS MARC and MBRS Program, Barry University.

10:15 am, BREAK

10:30 am, BIO-35E Wing-loading and Minimum Flight Temperature in Two Periodical Cicadas (Homoptera: Cicadidae: *Magicicada septendecim* and *M. cassini*). A.F. SANBORN AND T.H. DAVIS, School of Natural and Health Sciences, Barry University, Miami Shores, FL 33161. Temperature effects all aspects of cicada biology, from when a population emerges to muscle contraction kinetics. Previous cicada studies have demonstrated a relationship between habitat and the minimum body temperature necessary to produce a controlled flight. A flying animal must product sufficient life in order to remain airborne. Theoretically, animals with lower wing-loading (greater wing area for a given body mass) should require a lower frequency of flight muscle contraction in order to produce the necessary life to generate flight. This means minimum flight temperature should increase proportionally with wing-loading. With this study we analyze the relationship of wing-loading and the ability of the cicadas to fly. Supported in part by Minority Access to Research Careers Grant 299420.

10:45 am, BIO-36E A Comparative Study of Heat Loss in Three Ratites: Ostrich, Emu, and Double-wattled Cassowary. P.K. PHILLIPS (1) AND A.F. SANBORN (2), (1) Department of Physiology and Biophysics, University of Illinois, Urbana, IL 61801, (2) School of Natural and Health Sciences, Barry University, Miami Shores, FL 33161. Surface temperatures of the ostrich (*Struthio camelus* Linné), emu (*Dromaius novaehollandiae* (Latham)) and double-wattled cassowary (*Casuarius casuarius* (Linné)) were measured using infrared thermography at several ambient temperatures. A geometric model of a large bird was created by combining proportionally sized spheres, flat plates and cylinders. Instantaneous heat loss was calculated for each body part. A basal metabolic rate was estimated by combining heat loss from the various regions. Areas specialized for heat loss were determined and the ability of each species to control surface temperature was evaluated. Supported by USPHS Traineeship GMS07143 (PKP). We wish to acknowledge the help and cooperation of Brookfield Zoo.

11:00 am, BIO-37E Genetic Mapping of Lethal Yeast Sphingolipids Mutants. C.S. VERRIER (2), J.R. AZEVEDO (1), AND K.D. ATKINSON (1), (1) University of California, Riverside, CA 92521, (2) Barry University, Miami, FL 33161. Baker's Yeast, Saccharomyces cerevisiae sphingolipid mutants generate endogenous ethanolamine that circumvents chol ethanolamine auxotrophy. About 10% of all eam mutants are temperature-sensitive lethal (tls) and cannot grow at 37°. To facilitate genetic mapping of the new tsl eam mutants, the parental strains had genetic markers built into them. Eight independent lethal eam mutants were mapped: 3 at eam1, 3 at eam5 and 2 at eam6. The tsl characteristic showed very low penetrance, suggesting that sphingolipid synthesis is coordinated with other cellular activities. Supported by NIH-NIGMS MARC Program, Barry University; U.S. Department of Education, PHS Grant GM37151.

11:15 am, BIO-38E Biological Impact on By-catch and the Environment of Scallop Trawl Fishing. MARTHA A. SAGER AND WALTER G. NELSON, Department of Oceanography/Ocean Engineering and Environmental Science, Florida Institute of Technology, Melbourne, FL 32901. The calico scallop (Argopecten gibbus) industry is a major Florida fishery, with Port Canaveral being a center of production. The most common gear used in scallop harvesting is a modified shrimp trawl. As with any fishing industry, the impact of fishing gear can have ecological and biological effects on non-target organisms in the immediate area, as well as on the surrounding environment. Three separate research cruises were taken off of Port Canaveral to examine the impact of trawl net fishing. A half scale version of a typical commercial scallop net was used. By-catch species were identified, and samples of surviving species were placed in aquaria for observation. On one cruise, grab samples were taken before and after trawling for grain size analysis and benthic organism analysis. Species affected by the fishing process included several species of flounder (Bothus), as well as portunid crabs. Grain size analysis showed a substantial increase in grain size in "after trawl" samples as compared to "before trawl" samples. There did not appear to be a major impact from scallop trawling on commercial fishery species.

ENGINEERING

Saturday, 9:30 am - 12:00 am, Room 1-129
Pat Mangonon, Florida Institute of Technology, Presiding

Saturday, 9:30 am
SECTION MEETING: ENGINEERING
Pat Mangonon, Presiding

10:00 am, ENG-1 Influence of Spacing on Discharge from Low Head Nozzles. MONICA H. BOYD AND S.C. KRANC, University of South Florida, Tampa, FL 33620. Pan distributors and drain gratings incorporate numerous small orifices located in close proximity to one another. The purpose of this investigation is to examine the effect of spacing on hydraulic performance. Measurements of discharge were conducted for single and double orifices at various spacing ratios. For single nozzles it was found that at low submergence the flow regime changes from true orifice flow to a weir flow. However, this transition was complicated by the formation of the "bathtub vortex" above the orifice. Nozzle pairs show a marked increase in discharge of low head and close spacing. Further experiments were conducted to examine vortex suppression.

10:30 am, ENG-2 Control of Storm Outflows from Detention Ponds. KEVIN C. McCARTY AND S.C. KRANC, University of South Florida, Tampa, FL 33620. Detention ponds serve both to improve the water quality and to limit the quantity discharge of runoff from developed areas. The purpose of the present study is to examine the mitigation of stormwater runoff by control weirs. Using recently obtained data for the hydraulic performance of typical control structures, a time dependent analysis for discharge from the pond has been made. These results demonstrate the sensitivity of pond stage to weir parameters. Design procedures are reviewed and extended. This work was supported by the Florida Department of Transportation/Federal Highway Administration. The opinions, findings and conclusions presented are not necessarily those of either agency.

11:00 am, ENG-3 A Method for Smoothing Dirt Roads. R.W. LOWRIE, 101 Lowrie Ln, Dade City, FL 33525. "Washboarding" on the thousands of miles of dirt roads in Florida forces traffic to either move very slowly or suffer damage and discomfort from severe vibration. The standard cure to washboarding is road grading, which is slow, expensive, and consequently infrequent. An older method, dragging, is reconsidered and an apparatus is described which rapidly removes the corrugations without special equipment or trained operators, based on road tests.

11:30 am, ENG-4 Engineering in Ant Hills. E. MIESAK, 11528 B. Wagon Rd., Orlando, FL 32826. Certain types of ants build a funnel-shaped hill surrounding their entrance/exit hole. Measurements of many of these ant hills in Central Florida demonstrates that certain constructional parameters of these hills remains constant. Engineering data is used to substantiate the claim that these funnel-shaped hills are purposely built to specific angles which are dictated by the soil type where these ant hills are constructed.

ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCES

Friday, 9:00 am - 12:00 am, Room 229
R. Del Delumyea, Millar Wilson Laboratory, Jacksonville University, Presiding

9:00 am, ENV-1 Efforts to Extract Cadmium from Industrial Phosphoric Acid Using Chelating Agents. C.D. NORRIS AND D.F. MARTIN, Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620. This study is concerned with the removal of cadmium ion from phosphoric acid by the use of chelating agents. Worldwide, the concentration of cadmium in mined phosphate ore ranges from 2-340 ppm, and in the manufacture of phosphoric acid, about 80% of the cadmium in the ore is carried along to the acid. Florida phosphate is relatively low in cadmium content, 5-16 ppm, but even this level may be unacceptable in the future. The cadmium can be removed from the ore or from the acid, and the investigation of possible removal from the acid seemed a logical beginning. The extraction of 10 ppm of cadmium from phosphoric acid was attempted using a number of chelating agents that were effective under acidic conditions with other metals. The study was expanded to determine the ideal amount of chelating agent to be used in the extraction. Duraphos APO 153 showed a significant cadmium extraction.

9:15 am, ENV-2 Isolation and Characterization of a Hydroxamate Siderophore Produced by *Lyngbya Majuscula*. E. GROSS AND D.F. MARTIN, Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620. *Lyngba majuscula*, a common blue-green alga adapted to freshwater, showed significantly greater weight gain when grown in iron-sufficient media than *L. majuscula* grown in iron-deficient media. A similar demand for iron in many microbes induces the production of iron chelators known as siderophores. Siderophores of the hydroxamate class are known to be produced by at least two other cyanobacteria. A chloroform soluble extract from *L. majuscula* iron-deficient media gave a positive Csaky test, indicating the presence of a bound hydroxamate. Visible, IR, and NMR spectra of the pure Csaky positive fraction of the extract have been used to attempt to elucidate the molecular structure of the siderophore.

9:30 am, ENV-3 Thallium in Organic Synthesis. V.V. NARAYANAN, L. MANDELL, AND D.F. MARTIN, Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620. The catalytic effect of chiral metal complexes was first reported in 1966. Metal complexes have been developed as soluble discriminating molecular catalysts. We are examining the use of beryllium complexes of the type $Be(AB)_2$, where AB is a ß-diketonate ion of the type $RCOCH_2CO'$ and thallium compounds of the type $R'RTl(R''COCH_2COR)$ as agents for enantiospecific synthesis.

Compounds of this type have been prepared by Institute members of methods of synthesis are straightforward. Recently Tl(III) ions have been known to induce highly stereospecific cleavage and skeletal rearrangement of certain cholesterol derivatives. Currently we are repeating one of the known reactions of Taylor (oxidative rearrangement of alkene using thallium(III) nitrate) TTN before we proceed to test the potential of complexed thallium compounds in asymmetric synthesis.

9:45 am, ENV-4 Dolomite Extraction from Phosphate Pebble by Aqueous Carbon Dioxide in Aqueous Ammonium Sulfate Buffer. Y. PAN, R.F. BENSON, AND D.F. MARTIN, Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620. As the high grade deposits of phosphate rock are depleted, future sources of P_2O_5 will be derived from lower grade ores. Processing to remove MgO, CO_2, Fe_2O_3, and Al_2O_3 in the lower grade rock will be necessary because these impurities cause both processing problems and degradation of product quality. Magnesium is probably the most serious impurity in the phosphate rock. It is present as a dolomite mineral that is partially encapsulated within the phosphate rock matrix. Methods are being developed to solve this problem. Our research focuses on leaching magnesium from phosphate pebble in dilute ammonium sulfate solution with carbon dioxide. Phosphate rock, gypsum and calcium carbonate can be filtered from the leaching system and washed for the production of phosphoric acid. This is an ongoing project supported by the Florida Institute of Phosphate Research.

10:00 am, ENV-5 Effects of Selected Copper(II) Chelate Compounds on Rates of Oxygen Production by Filamentous Algae. J. DYER (1), D. FORGIE (2), B.B. MARTIN (2), AND D.F. MARTIN (2), (1) Gaither High School, 16200 N. Dale Mabry, Tampa, FL 33618, (2) Institute of Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620. Copper compounds have been used for about 95 years to control algae in lakes, reservoirs, and canals in the United States. Lately, more concern has been expressed about the fate of the copper-containing herbicides. For example, 40,000 pounds of copper ion (either as copper sulfate or as chelated-copper) are added each year to the Hillsborough River and to Lake Manatee to control filamentous algae. The concentration of free copper ion can be maintained through the use of chelating agents, and it is free copper ion that presumably effects the growth of the algae. Though this fact has been verified for marine algae, it appears to be inferred for freshwater algae. The present study is an examination of the effects of selected coordination compounds on the growth of several filamentous algae.

10:15 am, ENV-6 Multi-Detector System for Gas Chromatography. PAUL C. BAUER AND ROBERT S. BRAMAN, University of South Florida, Department of Chemistry, Tampa, FL 33620. With the exception of the mass spectrometer, detectors for gas chromatography (GC), while sensitive, are not very selective. By observing the emission bands from CH, CN, and C_2 and the lines from H and C the identification of an organic molecule separated by GC may be possible. The design, characterization and implementation of a detector system to observe these emission signals will be discussed.

10:30 am, BREAK

10:45 am, ENV-7 Trace Nitrosamines in Environmental Samples. ROBERT S. BRAMAN AND MITCHELL F. KATZ, Department of Chemistry, University of South Florida, Tampa, FL 33620. Inorganic nitrogen oxide compounds can potentially result in the formation of N-nitrosamines if coincident with secondary amines. Study of N-nitrosamines requires a highly sensitive and selective detection method. Such a method has been developed utilizing acidic reducing media and subsequent chemiluminescent detection.

11:00 am, ENV-8 Preparation and Application of Supported Chelating Agents for Trace Ion Control. R.F. BENSON AND D.F. MARTIN, Institute of Environmental Studies, Department of Chemistry, University of South Florida, Tamp, FL 33620. The use of high porosity, high surface area, inert solid substrates to support reactive phases has been in use many years. Solid substrates to support liquid phases has been the basis for liquid and gas phase chromatography techniques. Sulfuric acid has been supported on silica gel and used to treat mineral oil with a resultant improvement that is at least 4 times more effective in terms of dosage required to meet product quality than conventional liquid-to-liquid treatments. Supported chelating agents have been shown to be successful in the treatment of aqueous solutions for ion extraction. In particular, a ß-diketone supported upon a solid substrate has been used to extract copper ions from solution to levels of approximately 1 ppm. This treatment shows an advantage over a conventional liquid-liquid extraction technique. Other metal ion chelating agents are planned for supported applications.

11:15 am, ENV-9 XPS Spectra of [Pt(dien)X]Y Complexes. J.W. PALMER, W.E. SWARTZ, JR., D. KING AND J.A. STANKO, Department of Chemistry, University of South Florida, Tampa, FL 33620. Using X-ray Photoelectron Spectroscopy (XPS), binding energies of inner shell electrons of platinum and ligand atoms were obtained in the series of complexes [Pt(dien)X]Y where $X = CN^-$, NO_2^-, Cl^-, Br^-, I^- and NO_3^- for selected counter ions, $Y = NO_3^-$, Cl^-, Br^-, or I^-. The variation of the Pt binding energy as a function of the coordinated ligand, X, was established. The ordering reduced for the X-ligands was compared with that for these ligands in the spectrochemical series, the nephelauxetic series and the tans-effect in platinum(II) complexes.

11:30 am, ENV-10 Hazards in the Home/Workplace. N.G. ALEXIOU M.D., M.P.H. (1) AND D.F. MARTIN (2), (1) 400 Island Way, Apt. 202, Clearwater, FL 34630, (2) Institute of Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620. The Florida Occupational Medical Association has supported placement of an information system in the Institute for Environmental Studies. The system consists of an IBM PC AT computer, with color monitor, laser disc reader, a set of CD-ROM (compact disc, read-only memory) discs from the Canadian Center for Information Services, and a printer. Each disc contains the equivalent of 250,000 typed pages, and the information on the discs is updated quarterly. Three of the four published discs are available at the Institute, and an available program allows outside users to call in and access the information system. The databases available include: MSDS, CHEMINFO, RTECS, Hazardous Materials (46 CFR), and NIOSHTIC databases. A wealth of information is available on the properties of substances, as well as a summary of available literature.

11:45 am, ENV-11 Relationship between Urban Population and Atmospheric Elemental Carbon Concentration in Geographic Locales in the U.S. R. DEL DELUMYEA, Millar Wilson Laboratory for Chemical Research, Jacksonville University, Jacksonville, FL 32211. The elemental carbon content of urban aerosols has been shown to be related to population. The effect of the presence of inorganic species on the darkness of filters containing these aerosols was the subject of a previous paper. The present paper discusses evidence that background (soil) composition may have an effect on the apparent relationship between elemental carbon and population. The magnitude of the effect depends on the geographic location of the sampling site.

Friday, 12:00 am
SECTION MEETING: ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCES
R. Del Delumyea, Presiding

FLORIDA COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS

Friday, 9:00 am - 11:30 am, Room 1-230
Session A
Ray Ashton, Water and Air Research, Inc., Presiding

9:00 am, REB-1A Gopher Tortoise Density in Coastal Scrub: Flagler County. B.G. CHAREST, Department of Natural Resources, Division of Recreation and Parks, District 4 Administration, 1340-A A1A South, St. Augustine, FL 32085. Burrows of gopher tortoises were surveyed in two adjacent, recently burned zones at Washington Oaks State Gardens, Flagler County. Burrow sizes, distribution and activity levels (active, inactive or old/abandoned) were determined in the initial surveys in the fall of 1991. The standard occupancy rate correction factor of 61.4% of active plus inactive burrows was used to estimate population densities of 17.2 and 4.3 tortoise per acre in the saw palmettos strand and oak scrub habitats, respectively. Follow-up surveys of the same burrows were conducted in order to determine site-specific correction factors. Demographic health of the population appears to be good. Prescribed burning in these coastal scrub ecosystems is recommended.

9:15 am, RFB-2A A Contribution to the Ecologic Geography of the Western Atlantic Loggerhead and Green Turtle from Analysis of Remote Tag Recoveries. J.L. GUSEMAN AND L.M. EHRHART, Department of Biology, University of Central Florida, Orlando, FL 32816. Since the UCF Marine Turtle Research group began tagging sea turtles in Brevard County, Florida in 1973, fifty adult female loggerheads have been recovered at distances greater than 150 km. Three routes of travel are evident from the recoveries. About 25% of the recoveries come from turtles crossing the Florida Current to northern Bahama Islands. Another 25% were recovered in Cuba mainly along the northern coast. Another group almost 25%, apparently never cross the Florida Current and generally hug the west coast of Florida. Crossing the Florida Current evidently influences at least some of the post-nesting loggerheads by temporarily carrying southbound post-nesters northward with the current as they attempt to cross it. Little is known of the ecologic geography of the

Florida green turtle. To our knowledge, no adult green turtle nesting on Florida's beaches has even been recovered on a foraging ground. However, two juvenile green turtles captured in Mosquito Lagoon, Florida during cold-stunning episodes have been recovered, one in Cuban waters and the other off Bluefields, Nicaragua.

9:30 am, REB-3A Trends in Loggerhead and Green Turtle Population Densities in Florida's East Coast Lagoons: The Usefulness of CPUE Analysis. L.M. EHRHART (1) AND W.E. REDFOOT (2), (1) Department of Biology, University of Central Florida, Orlando, FL 32816, (2) Seminole Community College, Sanford, FL 32773. The use of large-mesh nets to capture marine turtles for studies of in-water populations has increased over the past decade, but there has been no attempt to standardize methods of data analysis. The results of our deployment of nets for 1382 hours over the past 10 years suggest that Catch-Per-Unit-Effort (CPUE) is useful for analysis of long-term and seasonal trends. We suggest that "km-hr" (1000 m of net soaking for one hour) be adopted as the standard unit of effort and that our long-term CPUE means (0.75 captures/km-hr for loggerheads; 1.06 captures/km-hr for green turtles) be viewed as arbitrary standards against which other results can be compared.

9:45 am, REB-4A Reproductive Ecology of the Florida Green Turtle (Chelonia mydas): Results of Field Work at Melbourne Beach, FL. 1991. STEVE A. JOHNSON, University of Central Florida, Orlando, FL 32816. The population of green turtles that nest on Florida's beaches is poorly researched. Nightly surveys were conducted during the summer of 1991 at an important nesting beach in south Brevard County to study certain aspects of reproduction in the Florida green turtle. From June 7 through September 6 a total of 28 females were encountered 98 times. Mean straight line carapace length was 102.5 cm(n=25). Nesting surveys recorded 161 Florida green turtle nests. Mean clutch size was 133 (n=103). Reproductive success was evaluated for 99 in situ nests. Mean hatching and emerging success rates were 54.35% and 53.35%. Site fidelity, mean number of clutches deposited per female, and mean renesting intervals were determined. Given the relatively large number of nestings as well as the high reproductive success rate, preservation of Melbourne Beach through land acquisition and inclusion in the Archie Carr National Wildlife Refuge is essential to conserve the Florida green turtle.

10:00 am, REB-5A A Spatial and Temporal Comparison of the Morphometrics of Juvenile Green Turtles and Subadult Loggerheads in the Central Region of the Indian River Lagoon. W.E. REDFOOT (1), L.M. EHRHART (2), AND J.L. GUSEMAN (2), (1) Seminole Community College, Sanford, FL 32773, (2) Department of Biology, University of Central Florida, Orlando, FL 32816. The morphometrics of juvenile green turtles and subadult loggerheads in the central region of the Indian River Lagoon System were found to be similar to those at other locations along the U.S. Atlantic coast. With the curious exception of loggerhead head width, statistical analysis of the morphometrics of both species did not reveal any significant within-year differences. A between-year analysis of data from 1983 to 1989 showed a significant decline in green turtle morphometrics, but did not show any significant change in loggerhead morphometrics.

10:15 am, REB-6A Operations Research and the Manatee Problem. R.P. HAVILAND, MiniLab Instruments, Daytona Beach, FL. Several basic principles of the military discipline called Operations Research are applied to the problem of Manatees and high speed boats. Sweep rate, lethality, collision avoidance and exchange rates are considered. It is concluded that real recovery of the Manatee population will require marked reduction in kill rate. The influence of several factors on this is shown.

10:30 am, BREAK

10:45 am, REB-7A Microhabitat differences in space use by Podomys floridanus in xeric pinelands. A.M. BARD (1) AND I.J. STOUT (2), (1) DNR, 12549 State Park Drive, Clermont, FL 34711, (2) Department of Biology, University of Central Florida, Orlando, FL 32816. We examined the association between microhabitat features and capture frequency of the Florida mouse, Podomys floridanus in 3 phases of xeric pineland: a) sand pine scrub, b) xeric oak scrub, and c) xeric longleaf pine-wire grass. Each study site was isolated from the others by more than 500m. Over the 11-months of study, 46 individual Podoyms were captured on the sand pine scrub site; 2 individuals were captured in the xeric oak scrub. Posomys was never captured on the longleaf pine site. Capture locations were classified as: a) near a gopher tortoise burrow, or b) distant from a tortoise burrow. Numerous burrows were present on each site. The working hypothesis was that captures of both sexes in each season would be equal among the trap stations regardless of microhabitat differences. Based on 165 captures over 4 seasons (11 months), the hypothesis could not be rejected ($p > 0.05$). Regardless, more captures ($n=94$) were at burrows than in their absence ($n=71$). There was a strong tendency for female Podomys to be captured at burrow locations in summer (17 or 23) and fall (12 of 16). Fluorescent pigment was employed to track individual mice to post-release escape burrows. Escape sites were inconspicuous mouse-sized burrows near tortoise burrows, most of which had been abandoned for years. Vegetation structure rather than availability of home sites appeared to explain the local distribution of Podomys.

11:00 am, REB-8A Activity and Diet of an Urban Population of Big Cypress Fox Squirrel. PATRICK G.R. JODICE (1) AND STEPHEN R. HUMPHREY (2), (1) Florida Game and Fresh Water Fish Commission, Lake City, FL 32055, (2) Florida Museum of Natural History, University of Florida, Gainesville, FL 32611. Activity and diet of Big Cypress fox squirrels (Sciurus niger avicennia) were studied for 1 year on 4 golf courses in Naples, Florida. Percentage of time spent foraging and inactive varied seasonally. Diets also varied among seasons. Seasonal changes in foraging and inactivity were not correlated with changes in diet and weather, and the seasonal dietary shifts that did occur did not alter the time spent foraging. Mating behavior and young rearing may have the strongest effect on seasonal activity patterns. The value of golf courses may be maximized by leaving native trees in place and planting exotic trees with long reproductive seasons.

11:15 am, REB-9A Status and Distribution of the Long-tailed Weasel in Florida. J.A. HOVIS, Florida Game and Fresh Water Commission, Nongame Wildlife Program, Ocala, FL 32674. A status survey of the long-tailed weasel (Mustela frenata) in Florida was conducted between April 1990 and March 1991. No weasels were captured during 4493 trap nights of effort, but 182 occurrence records were obtained from the literature, state and private collections, and reported sightings. These data revealed that long-tailed weasels occur throughout Florida, excluding the southeastern portion of the state, and are most active during the late fall and winter. Weasels were documented in 12 different habitat types, with the most records occurring in upland forests, agricultural lands, and lowland forests. The species is apparently an opportunistic carnivore that may be more limited by the availability of its prey than by habitat.

11:30 am, LUNCH BREAK
SECTION MEETING - FLORIDA COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS
Ray Ashton, Presiding

Friday, 3:00 pm - 4:45 pm, Room 1-230
SESSION B
Paul Moler, Florida Game and Freshwater Fish Commission, Presiding

3:00 pm, REB-10B Aerial Studies of the West Indian Manatee (*Trichechus manatus*) on the West Coast of Florida from 1985-1990: A Comprehensive Six Year Study. JESSICA J. KADEL AND GEOFFREY W. PATTON, Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota, FL 34236. Monthly aerial surveys have been conducted from Anna Maria to Venice, Florida since 1985. In 1987, a southern region was added to include the waters from Venice to Northern Charlotte Harbor and the Myakka River. An average of 51 manatees were seen per flight for both northern and southern areas. The maximum populations was estimated to be 44 for the northern area between 1985-1990 and 123 for the entire area from 1987-1990. Average herd size (2.1) and calf percentages (9.0% for N, 13.3% for S, and 11.8% for entire region) have remained relatively constant although a higher calf percentage in the south suggests its importance as a nursery area. The six years of data show population trends for the entire area as well as in several specific sites with recurring manatee use such as Pansy Bayou, Forked Creek, Turtle Bay, Buttonwood Harbor, and the Myakka River. This is the longest running study of non-winter habitat utilization.

3:15 pm, REB-11B The Distribution of the Blue Spring Hydrobe (Aphaostracon asthenes) in Blue Spring Run, Florida. B.A. BATES (1) AND M.A. REITER (2), (1) Department of Biology, Stetson University, Deland, FL 32720, (2) Department of Biology, Seminole Community College, 100 Weldon Blvd., Sanford, FL 32773. Aphaostracon asthenes, a protobranch snail endemic to the Blue Spring Run of Volusia County, Florida, has an unknown distribution within the run. Sampling plots of 400 cm^2 were randomly selected across eight separate stations along Blue Spring Run for determining the distribution and substrate preference of A. asthenes. The stations were also tested for various physical and chemical parameters. A. asthenes was most abundant in shallow, moving, well-oxygenated waters, and on limestone substrate as opposed to mud, humus, or plant material. A. asthenes was found in high numbers only near the boil of the spring, disappearing downstream as the amount of fresh limestone decreased.

3:30 pm, REB-12B The Hydric Pine Flatwoods of Southwest Florida: A Community Profile. J.W. BEEVER III AND K.A. DRYDEN, Office of Environmental Services, Southwest Florida Field Office, Florida Game and Fresh Water Fish Commission, Punta Gorda, FL 33955. The hydric pine flatwoods of southwest Florida provide regionally significant hydrologic, fishery, and wildlife habitat values. The lack of recognition of this habitat has resulted in conflicting regulatory and resource management of this habitat, with a subsequent disproportionate loss of this habitat. The unique value to wildlife of the hydric pine flatwoods of southwest Florida is that the same habitat functions as both a wetland and an upland. To date we have identified 239 vertebrate species from the hydric pine flatwoods of southwest Florida, including 20 state listed species, 2 USFWS candidate species, and 4 CITES species. Regionally the hydric pine flatwoods are critical for Florida black bear, Florida panther, wood stork, red-cockaded woodpecker, bald eagle, eastern indigo snake, gopher tortoise, Big Cypress fox squirrel, Sherman's fox squirrel, Bachman's sparrow, bobcat, and Florida long-tailed weasel.

3:45 pm, REB-13B Do Wetland Mitigation Sites in Urban Landscapes Have Wildlife Habitat Values? A Case Study. D.L. LEONARD (1), R.B. HUPALO (2) and I.J. STOUT (1), (1) Department of Biology, University of Central Florida, Orlando, FL 32816, (2) St. Johns River Water Management District, Palatka, FL 32178. Mitigation for wetland habitat destruction has the potential to preserve biological diversity in urbanized landscapes. We documented wildlife presence on a linear wetland mitigation site in Orlando, Florida over a period of 31 months. Birds were sampled 3 times per month and fish, herptiles and mammals were sampled on several occasions to ascertain species composition. Seining revealed 12 species of fish in the channel. Trapping with drift fences yielded 12 species of herptiles. Seven species of mammals were either captured or observed on the site. Forty-eight species of birds were observed; 12 of 48 species were detected once. Feeding guild composition was: carnivores (27.8%), grainivores (22.2%), insectivores (30.5%), and omnivores (19.4%). In spite of the fact the mitigation site was a "restored" forested wetland, it supported a suite of generalist species that would be expected in natural habitat remnants.

4:00 pm, REB-14B A Mark and Release Study on the Southeastern Beach Mouse (Peromyscus polionotus niveiventris) on the Kennedy Space Center, Florida. J.A. PROVANCHA AND D.M. ODDY, Bionetics Corporation, BIO-2, Kennedy Space Center, FL 32899. A mark and release study of the southeastern beach mouse (Peromyscus polionotus niveiventris) was initiated on the John F. Kennedy Space Center (KSC) as part of long-term environmental monitoring activities to determine the current status of the beach mouse. Trapping was done on twenty-nine 150m long transects (trap intervals of 15m) on a quarterly basis from March 1990 through February 1991. A total of 539 beach mice were captured and 346 individual beach mice were tagged. Overall trap success for beach mice was 13.6% (539/3937 adjusted trap nights). Of the 539 beach mice captured, 190 were recaptures. Average distance between captures was 50m with the two longest distances recorded being 690m and 2440m. The KSC coastal strand appears to support a large number of beach mice.

4:15 pm, REB-15B Rare, Threatened and Endangered Species in Florida; The Local Perspective. HILARY SWAIN, Department of Biological Sciences, Florida Institute of Technology, Melbourne, FL 32901. It is not straightforward to determine, at the local level, which are the priority species for protection in Florida. Federal and State lists are behind schedule (excluding many species that are extremely threatened), include several species that are not particularly vulnerable, and do not delineate localities or regions that are crucial to the long-term survival of listed species. How, therefore, do we determine which rare species a specific region is especially important for? This paper will present data for Brevard County, Florida to demonstrate how to assess local priorities for species protection.

It will consider geographic distribution, habitat requirements, local population size, the center of the population distribution, and occurrence in existing protected areas. It will come up with recommendations for priority species in Brevard County which not only include the current well-known listed species, but a variety of other species for which the county is extremely important but which did not currently receive any local recognition.

GEOLOGY AND HYDROLOGY

Friday, 3:00 pm - 5:00 pm, Room 1-148
Gary Russell, U.S. Geological Survey, Presiding

3:00 pm, GHY-1 Mechanism for Rapid Cliff Retreat Along the Southeast Florida Coast. D.W. LOVEJOY, Palm Beach Atlantic College, West Palm Beach, FL 33416. A severe extratropical storm during the Fall of 1991 provided opportunities for observing first-hand the process of rapid cliff retreat along the Martin and Palm Beach County coasts. This storm generated swell waves that reached heights of 18-20 feet which pummeled the coastal cliffs for three days. During this interval several large masses of bedrock broke off the coastal cliffs and fell forward into the surf zone where wave abrasion is now attacking them from all four sides. The major factor involved in collapse of these bedrock masses is the presence of a deeply indented notch at the base of many cliffs. The presence of the notch makes the overhanging bedrock highly susceptible to attack by the impact of the breaking waves. Several theories are advanced for the formation of notches in lime-rich rocks along tropical and subtropical coasts.

3:15 pm, GHY-2 Hydrologic Effects of the 1988-90 Drought on Aquifers of Lee County, Florida. RICHARD K. KRULIKAS, U.S. Geological Survey, Fort Myers, FL 33901. Lee County, in southwest Florida, experienced a severe drought from 1988 to 1990, in which the annual rainfall was 4 to 16 inches below normal. The drought, along with a growing population, and increased pumpage placed a marked stress on Lee County's groundwater supply. The stress caused water levels in some wells to drop to record lows and also caused movement of the saltwater interface. All wells tapping the aquifers of Lee County, in which water levels were measured, showed a sharp decline in water levels during this period. Record lows in water levels occurred in one or two wells that tap the surficial aquifer, the sandstone aquifer, and the mid-Hawthorn aquifer. Saltwater intrusion was evident in the Bonita Springs area in southern Lee County where chloride concentrations increased from between 200 and 300 to 400 and 500 milligrams per liter. Rainfall for 1991 rebounded to above normal values, and water levels also rebounded; however, the recent 1991-92 winter dry season has again resulted in rapidly dropping water levels.

3:30 pm, GHY-3 Water Budget Analysis - Preliminary Results, Volusian Floridan Sole-Source Aquifer. R.P. HAVILAND, MiniLab Instruments, Daytona, FL. The concept of an aquifer water budget analysis program was described at the 1990 annual meeting of the Academy. The model considers rainfall, evaporation, transpiration, surface and internal layer vertical and horizontal flow, springs, leakage and use. Calibration and interpretation of results for the Volusian aquifer system is proceeding. A first finding was that the pre-development potentiometric level was surprisingly insensitive to rainfall variation. Search for reasons for the past-1955 level decline led to modification of the program to include the effects of drainage canals. Preliminary results of the combination of use, drainage and rainfall variation are included.

3:45 pm, GHY-4 Surface-Geophysical Investigation of Northeastern Palm Beach County, Florida. RICHARD L. KANE (1) AND GARY M. RUSSELL (2), (1) U.S. Geological Survey, Fort Myers, FL 33901, (2) U.S. Geological Survey, Stuart, FL 34997. Surface-geophysical techniques indicate a mud and marl unit from land surface to a depth of about 40 feet below land surface exists in a 323-square mile area of northeastern Palm Beach County. Direct-current resistivity and ground-penetrating radar, supplemented by hydrogeologic and water-quality data, were analyzed to determine the areal and vertical extent of the mud and marl unit.

4:00 pm, GHY-5 The Significance of Fossil Crinoids from Florida Limestones. CRAIG W. OYEN, Department of Geology and Florida Museum of Natural History, University of Florida, Gainesville, FL 32611. Tertiary limestones in Florida have preserved a large variety of fossil invertebrates which are valuable for paleontologic research. Fossil crinoids have not been described, or identified with certainty, from Florida strata until now, even though they have been reported as abundant constituents from Eocene sediments of the Coastal Plain in the southeastern U.S. This study has found several different skeletal components of comatulid crinoids, including centrodorsals, radial, basal and brachial plates, from 3 sample locations out of the late Eocene (Jacksonian) Inglis Formation and Crystal River Formation of the Ocala Group. Centrodorsals from the Inglis Formation are identified as Himerometra bassleri Gislen while at least one other taxon from the Crystal River Formation (centrodorsal component) is currently being identified. These fossils are important because their stratigraphic and biogeographic distribution may help further define patterns of the timing and distribution of Tethyan Seaway circulation during the Eocene already demonstrated by other fossil taxa.

4:15 pm, GHY-6 Patterns of Molluscan Extinction and Diversification in the Plio-Pleistocene Fossil Record of Southern Florida. E.J. PETUCH, Department of Geology, Florida Atlantic University, Boca Raton, FL 33431. Two major extinction events are present in the Plio-Pleistocene molluscan fossil record of southern Florida; one between the Caloosahatchee Formation and Holey Land Unit and one between the Bermont and Fort Thompson Formations. These extinction horizons separate three disparate, successional molluscan faunas. Kissimmean Faunas, containing genera such as Contraconus, Hystrivasum, and Siphocypraea, are confined to the Buckingham, Tamiami, "Pinecrest," and Caloosahatchee Formation Bellegladean Faunas, with genera such as Lindoliva and Miccosukea, are confined to the Holey Land Unit and Bermont Formation. Lakeworthian Faunas are essentially modern and are confined to the Fort Thompson, Anastasia, Miami, and Key Largo Formations. Repeated severe cooling events and eustatic lows during Nebraskan and Illinoisan times appear to be responsible for the two mass extinctions.

Friday, 4:30 pm
SECTION MEETING: GEOLOGY AND HYDROLOGY
Gary Russell, Presiding

PHYSICS AND SPACE SCIENCES

Friday, 3:00 pm - 5:30 pm, Room 1-251
Paul R. Simony, Jacksonville University, Presiding

3:00 pm, PSS-1 Active Control of Acoustic Impedance in a Waveguide. R.L. VOOR, Department of Physics, University of Central Florida, Orlando, FL 32816. A double layer of piezoelectric material is used in a sensor/actuator format in a waveguide to modify waves reflected from its surface. A computer is used to control the reflection condition, thus actively controlling the acoustic impedance in the waveguide.

3:15 pm, PSS-2 A New Solid State Laser of Ultrahigh Intensity. Y-F CHEN, P. BEAUD, E. MIESAK, B.H.T. CHAI, AND M.C. RICHARDSON, Center for Research in Electro-Optics and Lasers (CREOL), Orlando, FL 32826. We present the most compact ultrahigh intensity solid state laser system. This is based upon the newly developed laser crystal LiSAF. This new crystal has a unique feature of long fluorescence lifetime making flash lamp pumping possible. This system will be capable of delivering 1J of energy in 100fs which is 10^{13} watts in peak power. Focusing such a beam to a spot size of 10^{-4} cm would produce intensities as high as 10^{21} (W/cm^2). This is equivalent to an electric field strength of 10^{10} volts/cm, about ten times higher than the interatomic electrical field. One important application of this system will be to generate x-ray emission from laser produced plasma.

3:30 pm, PSS-3 Functional-Integral Approach to the Hubbard Model. A.F. DeLIA, Department of Physics, University of Central Florida, Orlando, FL 32816. Strongly correlated electron systems, such as those that exist in high-temperature superconductors, are studied using a functional-integral approach to the Hubbard model. In particular, the way in which the Hubbard model approaches its strongly correlated (t-J) limit is examined and the qualitative similarities and differences between the intermediate and strong interaction regimes are outlined.

3:45 pm, PSS-4 A Skewed Non-spreading Wave-packet that Breathes. D.S. BATEMAN, Department of Physics, University of Central Florida, Orlando, FL 32816. The effect of the spatial dependence of the potential on the evolution of a non-spreading localized wave packet is investigated through the example of a potential for which the energy levels are equally spaced but which has a shape quite different from that of a simple harmonic oscillator, for which localized wave packets were originally developed.

4:00 pm, PSS-5 Atomic Charge Transfer Revisited. P.R. SIMONY, Jacksonville University, Jacksonville, FL 32211. The charge transfer problem in atomic scattering has provided theoreticians with a series of challenges over the years. Recent work indicates certain projectile/target mass ratios for which present second-order calculations may not be adequate. A classical two-step model and a corresponding second-order Born series approximation will be used to analyze this difficulty.

4:15 pm, PSS-6 Micro-Raman Spectroscopy of Carbon Based Materials. R. VOOR, L. CHOW AND A. SCHULTE, Physics Department, University of Central Florida, Orlando, FL 32816. A simple system for spatially resolved Raman studies of solids and thin films has been constructed. Applications to diamond films and organic materials are presented.

4:30 pm, PSS-7 Speed of Light Measurement Using BaF_2 Scintillation Detectors. S. LUKACS, K. HOPKINS, AND L. CHOW, Department of Physics, University of Central Florida, Orlando, FL 32816. Table-top nuclear instruments are used to determine the speed of light. The Correlated 511 keV photons from a 100 μCi NA-22 source were detected by two BaF_2 scintillation detectors, and the prompt coincidence peaks were recorded as a function of one of the detector's distance. As a result, we found the speed of light determined to be $2.986(13)\times10^{10}$ cm/sec, which agreed very well with the theoretical value of 2.9979×10^{10} cm/sec.

4:45 pm, PSS-8 Measuring the Space Radiation Environment. PENELOPE S. HASKINS, Institute for Space Science and Technology, Gainesville, FL 32609. Space-based measurements provide an improved understanding of the space radiation environment and its effects on materials. The Shuttle Activation Monitor (SAM) experiment measures the radiation environment as it varies with orbit, detector material, and amount of shielding. The SAM has flown on STS-28, STS-44 and STS-48. Determination of the effects of the radiation environment on new sensor materials is the object of the Crystal Sample Package (CRYSP) experiment. Measurement of the induced radioactivity of the Long Duration Exposure Facility (LDEF) led to the first observation of the absorption of a cosmogenic radioscope on the surfaces of an orbiting spacecraft. (This work supported in part by the Strategic Defense Initiative Organization).

SOCIAL SCIENCES

Friday, 10:00 am - 11:15 am, Room 1-229
Gordon Patterson, Florida Institute of Technology, Presiding

10:00 am, SOC-1 Murder in Sixteenth Century Florida: The Strange Case of Pierre Gambie. G.M. PATTERSON, Florida Institute of Technology, Melbourne, FL 32901. The murder of the sixteenth century French adventurer, Pierre Gambie, is described in two contemporary narratives and one visual account. Gambie arrived in Florida in 1564 as part of Rene Laudonniere's party. Gambie left Ft. Caroline to seek his fortune among the native population. Gambie's rise to a position of power and violent death fascinated and horrified his contemporaries. This paper compares and contrasts Rene Laudonniere's and Jacques Le Moyne's descriptions of Gambie's murder.

10:15 am, SOC-2 Solitary Superpower: An Inquiry into the Criteria for a Global Power. M.N. COREY, 851 Brickell St. SE, Palm Bay, FL 32909. Since the end of the Second World War, the globe has been divided between two superpowers. The disintegration of the Soviet Empire and the emergence of Europe and Japan as economic and political powers offer evidence that the post World War II status quo is defunct. This paper will examine five essential characteristics (military power, economic strength, sufficient population, a willing government, and a sense of manifest destiny) that any nation or coalition of nations that wishes to achieve superpower status in the twenty-first century must achieve.

10:30 am, SOC-3 The Sense of Achievement and the Performance of Challenge. M. RAICH, Department of Psychology, University of Tampa, Tampa, FL 33606. The sense of achievement is often linked only to the finishing of a task offering some difficulty to complete. Data are presented showing that the sense of achievement is associated with the performance of challenges encountered during the process of task work. Feelings of achievement accompanying the performance of component task challenges are discussed as a factor of potential relevance to intrinsic motivation and task motivation.

Friday, 10:45 am
SECTION MEETING: SOCIAL SCIENCES
Gordon Patterson, Florida Institute of Technology, Presiding

FLORIDA ASSOCIATION OF PHYSICS TEACHERS

Saturday, 8:00 am - 9:30 am, Valencia Community College Buffet Room, Module 2

8:00 am, BREAKFAST, Valencia Community College Buffet Room, Module 2

9:00 am, BUSINESS MEETING

Saturday, 9:30 am - 11:45 am, Room 1-154
SESSION A
Bobbie Himes, Edgewater High School, Presiding

9:30 am
Report of the American Association of Physics Teachers, Orlando Winter Meeting, Alex Dickison, Florida Section Representative

9:45 am, APT-1A Oldies But Goodies. JIM NELSON (1) AND JANE BRAY NELSON (2), (1) Orange County Schools, Orlando, FL 39802 and (2) University High School, Orlando, FL 32817. Photogate timers are used for measurements in old experiments.

10:00 am **Third Annual Lowell Seacat Memorial Lecture**
The Microkelvin Laboratory at the University of Florida
Gary G. Ihas, Microkelvin Laboratory, University of Florida
Gainesville, FL 32611

11:00 am, BREAK

11:15 am, APT-2A Beginnings...Physics Workshops for Elementary School Teachers. ROBERT G. CARSON, Physics Department, Rollins College, Winter Park, FL 32789. It is becoming increasingly apparent that the choice of a possible career in science is made before high school. The first organized introduction to science occurs during the elementary school years, generally given by a teacher not versed in science. Since this teacher must deal with many other subjects, it is difficult to prepare units on the various sciences, especially the physical sciences. How can we facilitate the introduction of physical ideas at these grade levels? This paper explores several workshops on electricity and magnetism I presented to a group of elementary school teachers in Brevard County this school year. My goals were simplicity (without being dishonest), thrift (providing each teacher a "baggie" containing inexpensive equipment), and excitement (giving demonstrations using equipment the teachers could duplicate in the classroom, as well as demonstrating fancier equipment for the teachers' enrichment). Comments on both successful and unsuccessful parts of the workshop will be given as well as suggestions of what physics teachers can do for their elementary school colleagues.

11:30 am, APT-3A Spreadsheet Physics. LARRY BROWN (1) AND JACK BRENNAN (2), (1) Lake Mary High School, Lake Mary, FL 32746, (2) Physics Department, University of Central Florida, Orlando, FL 32816. This paper will discuss the applicability of utilizing Misner's and Cooney's book Spreadsheet Physics in an introductory physics course. This book instructs the reader in the basics of using: a spreadsheet, in particular Lotus 1-2-3; and in appropriate numerical techniques for the solving of interesting physics problems. The authors then work out many applications: projectile motion with drag, conservation of mechanical energy, pendulum, inelastic collisions, Kepler Motion, Rutherford Scattering, Dampened Driven Oscillator, waves on a rope, charged particle in a magnetic field. This paper will discuss the ease of using a spreadsheet to compute the trajectory of a sphere including air drag and lift due to the spinning of the sphere.

11:45 am, LUNCH, Valencia Community College Cafeteria

Saturday, 1:00 pm - 3:00 pm, Room 1-154
SESSION B
Bobbie Himes, Edgewater High School, Presiding

1:00 pm, APT-1B Videodisk and Computer Assisted Instruction. MARK LLEWELLYN, DOROTHY GAMBLE, DENNIS F. WEEKS AND JACK BRENNAN, University of Central Florida, Orlando, FL 32816. A lesson has been constructed on the Refraction of Waves using Side D of Physics Videoclassic Laser disks. The computer was set up to administer a test to determine the strongest learning style of the participant. The participant then enters a short essay into the computer on the refraction of waves. This is used to try to establish an initial entry level of knowledge. Appropriate video, textual and graphical information is then presented to the participant, based on learning style and level of knowledge. This paper will discuss the programming of the computer and the end product.

1:15 pm, APT-2B Interactive Physics Videodisks. BOBBIE HIMES, Edgewater High School, Orlando, FL 32804. This paper will present the work to date on a grant from the Orange County Schools to develop lesson plans to use the videodisk as an interactive laboratory experience. The videodisks, MacIntosh computer, and barcode reader are used in developing and using three lesson plans for high school physics at all levels.

1:30 pm, APT-3B Physics, Sports and Videodisks. MARY M. WINN, Chamberlain High School, Tampa, FL 33612. Grab the interest of your students by using the things they love--sports, technology and video--to teach them physics. The videodisk, The Physics of Sports, can be used to teach velocity, acceleration, force and momentum. The students first watch the sports event. Then, they advance the videodisk frame by frame to get measurements of distance and time. These measurements can be used to make calculations or draw graphs. Abstract concepts become real for the students and preconceived misconceptions vanish. A lesson will be demonstrated using a track and field event in a high school physics class.

1:45 pm, APT-4B A Physics Laboratory on a MacIntosh. MARY M. WINN, Chamberlain High School, Tampa, FL 33612. This particular presentation will show how to integrate a software package such as Interactive Physics into the curriculum and into your teaching methods. The presentation will discuss using it as a lecture tool and using it in a computer laboratory situation. The program has been called an animated blackboard and a sophisticated mechanics laboratory. No programming skills are necessary to design and run hundreds of experiments. Students can play "what if" by varying such things as friction and gravity. No longer limited by the one textbook illustration, they can try a wide variety of parameters quickly and easily. The computer does the work and all mechanical laws of the physical world hold. Vectors can be turned on or off as desired. Meters to show acceleration or velocity can be displayed or not. This program can be used in classes from elementary school to college.

2:00 pm, BREAK

2:15 pm, APT-5B The AP Physics Workshop - Past and Future. ALEXANDER K. DICKISON (1), AND JAMES R. HELMICK (2), (1) Seminole Community College, Sanford, FL 32773, (2) Lake Brantley High School, Altamonte Springs, FL 32714. Seminole Community College has hosted an annual AP Physics Workshop for Florida teachers for the past four years. This summer, the fifth workshop is being planned. Past experiences and future plans will be given. (Funded in part by TITLE II of Dwight D. Eisenhower Mathematics and Science Education Act).

2:30 pm, APT-6B Florida Teaching Certification Exam in Physics Institute: Preparation and Implementation. JAMES R. HELMICK (1), AND ALEXANDER K. DICKISON (2), (1) Lake Brantley High School, Altamonte Springs, FL 32714, (2) Seminole Community College, Sanford, FL 32773. An institute is being planned for Florida teachers who would like a review for the Florida Physics Teachers' Certification Examination. This institute is somewhat unique in that it must satisfy the needs of a variety of teachers. The format and early experiences will be described. (Funded in part by TITLE II of Dwight D. Eisenhower Mathematics and Science Education Act).

2:45 pm, APT-7B Applied Physics at Apopka High School. JAMES E. HOWARD, Apopka High School, Apopka, FL 32712. For the past three years Apopka High School has offered a physics course unique in that it targets average students who would not normally enroll in any physics course. These vocational students are enrolled in Principles of Technology in conjunction with our S.R.E.B./Blueprint program. This course is also unique in that it is organized in seven broad concepts of physics (e.g., force, work) each treated as a single unit with subunits detailing the application of that concept in mechanics, fluids, electricity and thermal systems. The emphasis is "hands-on," using computer interfaced labs and curriculum integrated software for problem-solving, word processing and database skills, integrated into lab reports.

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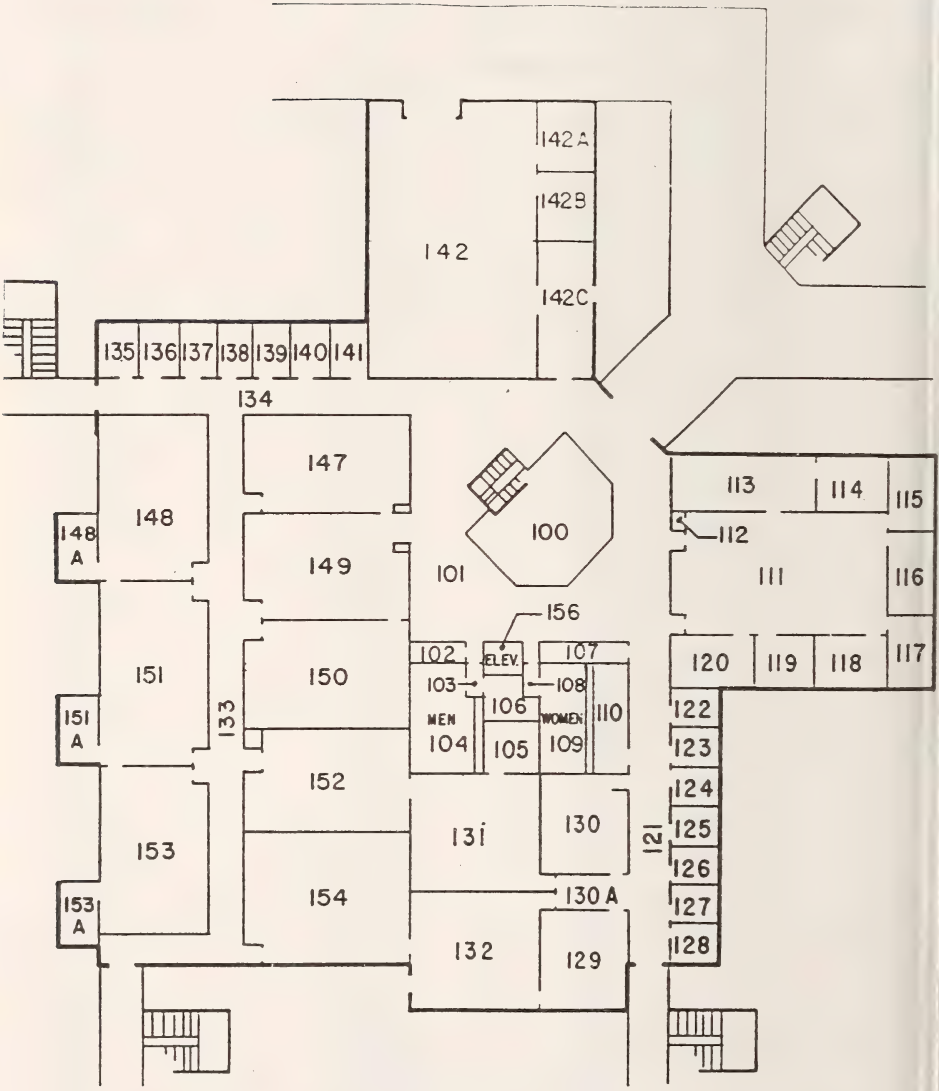
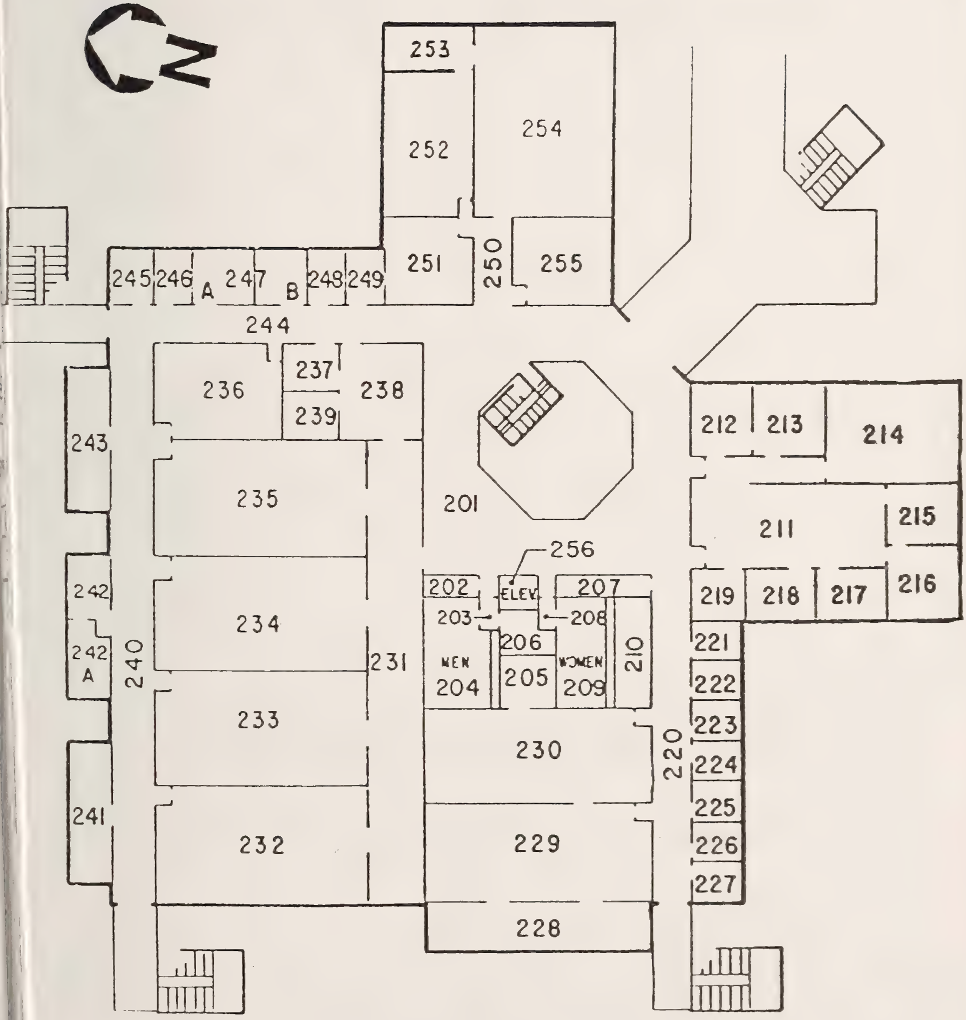
Remus, B.	18
Rhinesmith, P.	17
Rice, R.W.	4
Richardson, M.C.	31
Riddle, C.	4
Rochow, T.F.	17
Rosier, J.C.	13
Ross, A.	7
Russell, G.	29,30
Sager, M.A.	19
Sanborn, A.F.	18,19
Sanches, K.	18
Satterlee, D.	7
Schank, S.C.	1
Schoenberg, N.E.	8
Schulte, A.	31
Shibles, D.B.	3,4
Sibenthaler, J.	6
Simony, P.R.	31
Snelson, F.F.	12
Sollenberger, L.E.	4
St. Laurent, B.	6
Stanko, J.A.	23
Stewart, B.J.	9
Stout, I.J.	26,28
Strayer, J.	6
Strickler, J.A.	3,4
Sullivan, K.M.	14
Sumpter, D.	11
Swain, H.	28
Swartz, W.E.	23
Taren, D.	18
Tooze, C.A.	15
Verrier, C.S.	18,19
Voor, R.L.	31
Weeks, D.F.	34
West, S.H.	4
Whitney, R.	14
Winland, K.J.	7
Winn, M.M.	34,35
Wofford, D.S.	1
Yu, M.A.	9



MODULE 1
First Floor



MODULE 1
Second Floor

FAST

1992 ANNUAL CONVENTION

October 15 - 17, 1992
Tarpon Springs, Florida

Site of Sessions and Host Hotel:

Innisbrook

Conference center and resort hotel
All sessions will be held on site.
Post Office Drawer 1088
Tarpon Springs, Fl 34688
(813) 942 - 2000

For More Information Contact:
Bob Orlopp, Convention Co-Chairperson
Pinellas County Schools
301 4th St. SW
Largo, FL 34640 - 3599
(813) 588 - 6083

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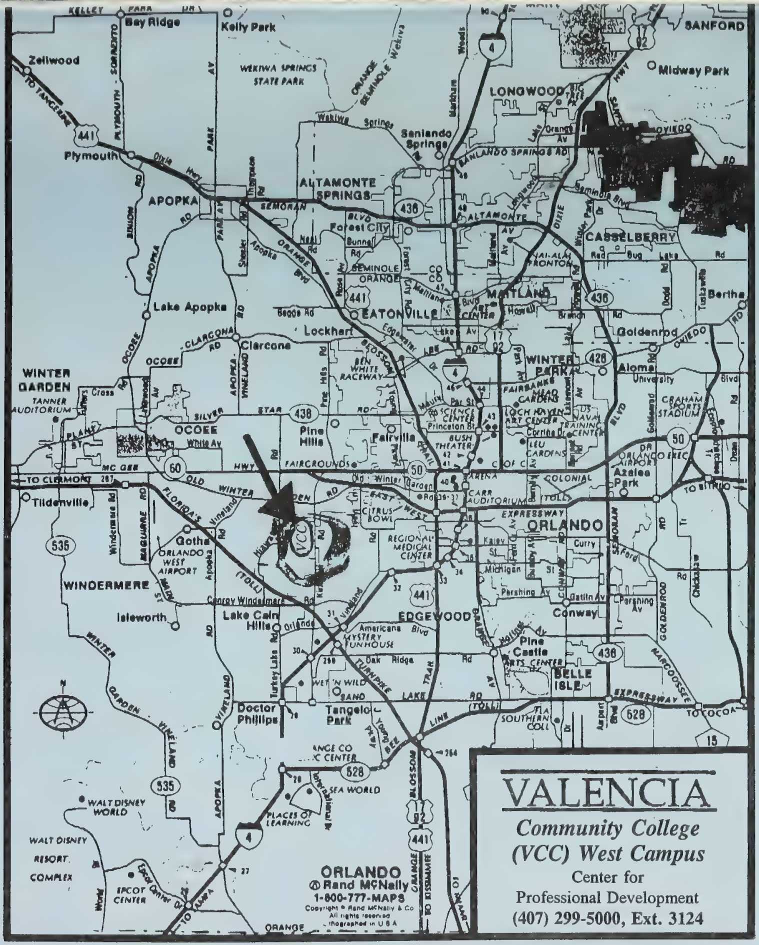

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Center for
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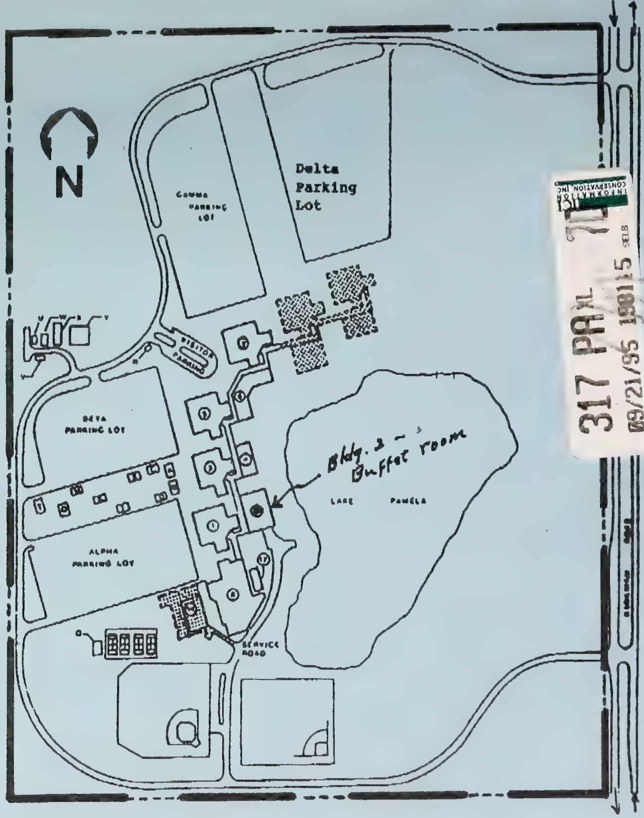
Orlando, FL 32811 (Exit 30-B from I-4)



Bldg. 3 – Buffet room

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